How To Become A Successful Electrician

L. Ellsworth Dodd.

How to Become A Successful Electrician

CONTAINING

THE STUDIES TO BE FOLLOWED, METHODS OF WORK, FIELD OF OPERATION, PROFESSIONAL ETHICS AND WISE COUNSEL

BY

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PREFACE.

The title of this little work is open to a variety of interpretations, and may call down different criticisms on the author. The nature of each criticism will depend upon the ideas the reader possesses of what constitutes success. When one of the wealthiest men in the United States died, and page after page of the daily papers was devoted to the story of his life, it must have occurred to many that a man who, as the sum of all those columns, could not secure a favorable comment had not lived successfully. Yet he began poor and ended rich, and these few words, it is to be feared, describe a very usual idea of success. There is no doubt that if this book told of a sure road to wealth, by means however questionable, it would be in great demand. Those who look in it for this will naturally be disappointed.

Prefaces are the least read portions of a book and this preface will share the common lot. Yet in it will be given in one word the basis and corner-stone of success for each reader. It is himself. If the reader is of the right stuff, and cares sufficiently for success, he will succeed. If he is not of this material, no book and no study will produce the result.

It seems a hard thing to say that honor and honesty are not in themselves favorable to progress in the accumulation of a fortune. He who, as he feels the end approaching, looks back on the long struggle and feels that honor was his guide and that he has wronged no man, who, as he thinks of his temptations, can know that he

has mercifully been allowed to escape without stain, can but tremble as he recalls the risks he ran, and accept an honorable life as a rich measure of good fortune. What value will a competence won by wrong methods have, when but a few years, and those at the wrong end of life, are left for its enjoyment? Leave to those who come after you a legacy of memories and traditions of a well-spent life, and you will be successful.

All this sounds like moralizing and may, by him who reads this preface, be interpreted as revealing the nature of the book itself. This it does; for the author's idea of success is here disclosed. He believes that the man who works for a fortune by good and bad means alike is a dreary failure, whether he reaches his goal or not.

The book is left now to the reader.

> "Perhaps it may turn out a sang,
> Perhaps turn out a sermon."

In either case, it will not be a very long one.

PREFACE TO THE TWELFTH EDITION.

A number of years having passed since the first appearance of this little book, the author has deemed it wise to revise and add new matter in an endeavor to bring the work up-to-date.

The many words of commendation which have been received, assure the author that the book has been a help and guide to many and lead him to a confidence in its continued usefulness.

April, 1903. THE AUTHOR.

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How to become a successful electrician is a problem which cannot be positively solved in words. The same qualities which make a good business man will go far to make a successful professional man. While the success or failure of life depends principally on the natural characteristics of the individual, it is possible and right to try to direct and guide the exertions of young aspirants, and to make their early work more directly conducive to the end in view.

The term electrician includes a very wide range of occupations. In laboratories some of the most exact work of the scientist is done in electricity. Such operations require a special training, which can only

be had in the laboratory, and which is generally acquired in the advanced school of science. It is obvious that the man fortunate enough to have graduated at one of our great universities as an electrician has little need of outside direction in the elements of his profession. During his college course the studies he must pursue are determined for him. The student less fortunate and equally adapted for science, who cannot take a college course, may find some words of direction and advice useful.

From the force of circumstances, this book, written principally for those who cannot go to college, must take special cognizance of electrical engineering. This is the great field for the self-educated electrician. From it he may graduate into the laboratory and take his part in original investigations, but it is fair to assume that he will first be an engineer.

An electrical engineer is one who works in some of the commercial and more directly practical branches of electricity. He may be a constructor of dynamos and motors ; he may go out of the shop and be entirely occupied in erecting plants ; or he may be in charge of such plants when running, having a hand in their erection or in the construction of the machinery. He is understood generally to deal with the larger forms of electrical apparatus. One who spends his time in minor operations, such as the measurement of capacities and resistances, would hardly be placed in the category of engineers.

In the laboratory of the richly endowed college, the holder of a professorship may devote much of his time to original research. His work may take the direction of determining electric factors, or of establishing the relations of electro-magnetic waves to light waves. He may try to solve the mystery of convection currents in a liquid, and of electrolytic convection in gelatinized solutions. Such work is hardly within the scope of the electrical engineer. The scientific investigator, confining his work to the realms of theory, is the ally and guide of the active operator. He finds his field in the laboratory, and his success is judged largely by the originality of his investigations. Faraday's discovery of the extra current, his observation of the minute spark produced when a circuit of high self-induction was broken, is one of his triumphs.

The engineer, on the other hand, is in the domain of active commercial life, dealing not with abstract theory, but with its applications. His success is judged not by any apparently fruitless achievement, but by the balance-sheet. The engineer's work must succeed commercially, and will be judged by his employers. To them he is a source of revenue, no more and no less.

A number of watts of energy are to be employed at some given locality distant from a central station. Shall a main be laid to the place in question, or shall a new station be established there? If a main, how

large shall it be? The theoretically satisfactory way is to keep to one station, so as to concentrate the generation of energy in one plant, and to supply it by a main of very low resistance to the distant point. Here the engineer has to look at the practical as opposed to the theoretical aspect. Which system will pay the best? He cannot pretend to put in a main of really low resistance, because of the original cost of the copper, and because of the interest which would be charged on the investment. He can put in a high resistance main within the limits of cost, but the loss of potential, inevitable to its use, involves the loss of energy, which means the waste of coal. A distant independent station will necessitate extra cost in generation of energy, but will such money loss exceed that due to the fall in potential in the small main? Can he make his main of such a size as to reduce the fall in potential to due limits, without incurring too heavy an interest charge?

Such problems as the above confront the electrical engineer, and his success in dealing with them must be measured by his finding the most economical solution. Compare his work with that of the original investigator. Faraday's tiny spark, a minute fraction of an inch in length, is one of the milestones of a life devoted to science. His purely theoretical work is at the basis of the profession to which this book is devoted. Yet the question of money never occupied Faraday. He sacrificed a lucrative practice simply

to devote his life to original work. His abstract investigations have had a part in making possible the practical work of to-day, and the electrical engineer was made possible by the disinterested and apparently useless work of many original investigators. No one could have seen in their primitive apparatus the fathers of the great dynamos of the present time.

The moral is to be slow to criticise unfavorably purely scientific work. It may seem useless, but none can tell what it will lead to. This lesson has been so well learned that there is little need of insisting upon it. No one hears an electrical engineer of any standing object to scientific investigation. He knows that his whole profession is based upon theoretical discoveries, and that he would have no *raison d'être* but for such work as that of Faraday and J. Clerk Maxwell. His field is still an unexplained mystery, and no one is more anxious for the theorist to explore it than is the enlightened engineer. So great is his respect for the scientist, that the tiny sparks of Hertz's experiments were hailed as a step towards the direct production of light. The practical world, now better educated and trained, which formerly thought so little of the extra current spark, looked with the utmost interest on its successor, the Hertz spark, still smaller and more insignificant in appearance. The engineer now sees at least the possibility of his apparatus rivalling in efficiency the fire-fly as a producer of light.

Thus the bonds that with the advent of electricity united the scientist to the engineer grew stronger every day. Electrical engineers are more highly educated than in old times, and many of them are capable of executing laboratory investigations themselves. The distinction between practical and scientific men has begun to fade away. No longer jealous of each other, they improve by mutual acquaintance. The scientist feels that he has a larger audience than before: the engineer hopes to derive much practical benefit from the college laboratory.

The principal object of this book is to give some hints to aspirants for the profession who have not the advantage of a college course. On all sides such aspirants may be found in the public schools, in the high schools, and in machine shops. On the farms as well, many a youth, when he sees the electric lights and electric cars in the neighboring village or city, feels that he would give all that he is worth to have some share in the work of the profession that annihilates darkness and space.

The first thing that such should understand is that it is an uphill road which they have to travel to become electricians. As competitors they will have college-bred men, fully as ambitious as themselves, and equally willing to do anything, provided it is electrical. The advantage of the college training is very great, but the lesson taught by the experience of successive generations, not only in this country, but

in the Old World, is that the poor man's son without any advantages of education can work to the front, and often passes his better equipped competitor. Years of hard work are before such young men, but they are years whose like has often been lived through, and will be lived through in the future, with ultimate attainment of success.

Assume that a young man of the classes suggested above desires to become an electrician. Perhaps the first thing to be determined is whether he is ready for any kind of work. Taking the class we speak of, the first object may be the earning of some wages or salary, even if small. In such case it is not too much to say that almost any position about an electrical works should be acceptable. It is even conceivable that a trolley-man, who understands electricity, might graduate as an electrician, first being promoted to work upon the line, thus entering on some more inspiring work than running a car. Even in attending to lamps, in collecting and distributing meter-zincs, and in similar work, a satisfaction will be felt in the realization of the fact that at least something is being learned, and that an apprenticeship to the profession is being gone through.

The question of age comes in. In our schools of science the entrance age is often seventeen or eighteen. Before entering, the student has to pass an examination of more or less scope and severity, which examination includes matter appertaining to his proposed

profession. This tells us that long before reaching the age of seventeen a young man may and should begin to study for his chosen profession. But those for whom this book is written are not all so young as this. Many may be well past the first four lusters of a hard-working life. The general moral, nevertheless, is obvious. The study may be begun in some sense at quite an early age. Those suited for the profession will have insensibly worked on such lines, for they will have excelled in arithmetic and branches of natural science, or at least will have received most permanent benefit from them. There is no harm in the public-school student trying to give his studies and his home work this direction. A scientifically disposed boy will find recreation in constructing batteries and electro-magnets, and perhaps in erecting a telegraph line between his home and that of some friend. If his home has an electric door-bell, he will be the one to keep it in order. His services may be in requisition among the neighbors for such things. If it is in a boy to become an electrical engineer, he will be apt to show it pretty early in life.

But how is such a book as this to help him? If he looks over its headings it may seem to him that an electrician has to be a very accomplished person. This is strictly true—true not only of the electrician, who deserves to succeed, but true of others as well. The first thing most people want to know is the easiest road to their desires. You wish to succeed as an

electrician—then your question, and it is a very rational one, is, How little is necessary?

Our book to some extent tries to answer this query. Take the sections one by one, and you will find that in each the endeavor is to give a clue to the least you ought to know.

In colleges all over the land young men are studying for the profession, and a severe four years' course is passed as preparation. This book details far less than the work of those four years, so the somewhat varied items of study and work are not a full course. The author's hope is in another direction. It is that, if the little work here outlined is faithfully done, the little study faithfully performed, and if what is catalogued here is absolutely known, the reader will be prepared to enter the field and compete for the top rungs of the long ladder, which it may take a life-time to ascend.

If you pick out just what suits your fancy—find that chemistry loses variety after a week at it and drop it; know that mathematics will not suit you and do not drop them only because you never take them up; read physics superficially, avoiding all formulæ and calculations—you have not got the stuff in you to succeed.

When through with this course, volts and ampères and their brethren should be as familiar to you as quarts and pounds are to the grocer. This may be brought about by practice on calculations of

circuits; Ohm's law, in its endless modifications, giving great chances for work in this direction. Energy, work (mechanical as well as physical units), inertia, force should be so ingrained by use in calculations and by the habit of referring all machinery motions and functions to them as to be a part of your nature. Your references to them should be almost instinctive.

This idea should be carried out in all that is detailed here. Little enough is prescribed—so little, that its only hope of utility is that the very short course of scientific study here mapped out shall become a part of your nature. Take this course and compare it with any college course and see how little there is of it—so little, that it may be a subject of just criticism were one to maintain that an electrician should go no further. This is not to be maintained by any means. But let a young man by his own exertions go thus far, let him become self-educated to this extent, and he will not be content to arrest his progress when on the border-land of science only. He will want to go further, and he will do so. Every step of such progress proves the true nature more than a year in college on the king's highway to knowledge—to knowledge little appreciated because so easily gained.

Enough has been said to indicate the general theory of work. If one will carry it out so as to learn a little bit very perfectly rather than a great quantity

superficially, a habit will be acquired which will stand one in good stead through life. Restrain ambition for covering ground. If you will begin slowly and thoroughly, you will do better in the end.

This much will introduce our subject. You think of entering a profession created within a comparatively few years upon a basis of pure science; one in which the old-time jealousy between practical and theoretical science is happily missing; one in which you will have to compete with minds as good and better than your own, and far better equipped. The great object in life is to acquire contentment. So before embarking in the competition satisfy yourself that you have the necessary qualifications to be an engineer; study your past proclivities and decide whether the farm, the store, or the machine-shop is not after all a safer field for you than electrical engineering.

Two boys live in a country village. The local surveyor is in want of some one to help him survey a farm or a lot. He will ask the boys which will help him. One offers, with signs of real interest, to assist. The other finds a game of foot-ball or of base-ball more interesting. Here is at once a clue as to which will make the best engineer. Let the same two boys live near a railroad. One will know the engines by their numbers and will know the characteristics of the different ones. A new engine will be an object of the greatest interest to him. He will

note the peculiarities of the tracks—how some are rusty and some bright. His mind will work upon the interesting question of why a travelled rail does not rust even on its sides where the wheels never touch it. If a new semaphore is put in, he will not be satisfied until he learns its exact uses. A little heap of sand by the rail-side will tell him that an engine has had trouble in starting, and that the sand-box has been opened to drop sand upon the rail. He will examine the sand to see what quality it is, and whether it has been baked to give it bite. Everything is to be investigated and its causes determined. The other boy will have a soul above (or below) such trivial things. But which boy would you select to make an engineer out of?

It is told of Agassiz that he wished to select an assistant from a number of young men. Taking them to a window he asked them one by one to tell what was there. Some noted only a house opposite, but one saw a house, saw that it was made of brick or of stone, described the material, and told of the general environment of the place. The good observer was selected as the assistant. The rejected applicants received a needed lesson; they learned that in Agassiz's estimation it was the observation of little things that indicated the scientific mind.

The moral of this is briefly told: Use your eyes. There is a multitude of things to be seen, if you will only look. The great things in any given line may

have been studied and worked out, but there always remain a multitude of little things to be investigated. Study to let none of them escape you.

The fire-fly, the glow-worm, the curculio of the West Indies are all small things. Yet on them the electrical engineer looks with envy and interest. He envies them their power of producing waves of almost pure light energy; he envies them their enormous efficiency as light-producers. They interest him because they give some faint suggestion and some very definite hope that the time may come when he will be able to light houses at a less reckless expenditure than that of two and a half or three watts to a candle-power.

A man who knows little hates to be forced to display his ignorance by being asked questions, while he who knows is always willing to respond to inquiries. Yet just in proportion to his knowledge, in proportion to the exact training which his mind has received, will he distinguish between sensible and idle questions. The mind of scientific bent wants to know everything, and all things cannot be ascertained by observation only. Questions must be asked, but of whom? Here again the natural qualifications will be shown. The born student will first propound his questions to his books or to those of some library, and if books do not tell him, he will not rest until he finds out in some way his point. His questions will be sensible ones—his own attempts to find

out for himself will insure this. He may ask them of one who knows; he may write to some journal which answers queries. Ignorance should cause restlessness until the desired information is obtained.

The reciprocal of what is outlined above is the willingness to impart our knowledge. If there is any one thing which shows what is worse than a limited intellect, it is the unwillingness to tell the little we do know in the way of science to those less informed. In this direction the mind should open for every one. Nowhere is candor more essential than in the field of science. In later life one may find out things which would be of value to professional men if published or made known. Then it is a duty to communicate them. But even in youth, the one who naturally helps along other inquirers less advanced than himself shows the true scientific bias. Conceal nothing in science. Secretiveness in those matters marks a one-sided character whose future prosperity may be doubted. To-day Cavendish is regarded as almost a criminal, because he concealed the valuable results of his researches in electricity. A miser in science is a sad anomaly.

It is definitely certain that we all have our individual characteristics. Some excellent minds would be utterly miserable in the engineering field, but there is no greater error than the falling into one-sidedness of character. An engineer should be an

"all-round man." He has to deal with human nature and with the luminiferous ether at one and the same time. If from the beginning a young man shuts himself up within himself, never opens his soul to any one, and works away in secrecy, he will ruin his chances of success, for a one-sided man is the last one who should adopt the profession of which we are speaking.

The writer has now in mind a young man who developed early in life a great talent for mechanics. His talent was fostered by his family—very properly, one would suppose. But with it was an accompaniment all too frequent—a desire to work alone, and a repugnance to companionship in his pursuits. This should have been combated but was not. The young man has become a recluse, only at home in his machine-shop, doing nothing for humanity, unknown to the world, a victim to one-sidedness. Another instance is within the writer's knowledge. It concerns again a born mechanic, a man who can do anything with tools, and who is accomplished in other ways. But him, too, a solitary life and one-sidedness have selected as a victim. He is devoted to his work, reads little, and does not do anything like what he should with the natural gifts which he possesses. It is evident that in both these cases rigorous measures should have been taken early in life, and both men should have been made to study literature, languages, or anything that would break

up their monotony of thought. It really seems that too great an aptitude for mechanics is as hurtful as too little.

For an engineer is concerned with the larger things of science. His business is to see that an electric plant is properly put up. A badly laced belt will give endless trouble. Buckled or warped grate-bars make proper firing much more difficult. He must have an eye for all these things. He may invent better grate-bars, he may lead his belt-lacing in a new and original way, but this does not say that he must personally spend his time in a machine-shop. His business is to be the Napoleon of his works or station—he must see that others do their work, and must understand each man's work, but he must not undertake to do it for them. Hence a great aptitude for lathe-work and operative mechanics must be balanced by a broadening of the mind and by the power of taking a comprehensive view of things. The examples just cited seem to have lacked this comprehensiveness. A man who can work to perfection on a hand-lathe—who can make a small and inadequate machine-lathe do work it was not made for—who can file up a true prism—may be proud of his skill, but he has only gone half-way to the goal of engineering.

A quality or characteristic to be avoided is sensitiveness. Sometimes, unfortunately, you may feel obliged to conceal your ignorance, and in general to

be so sensitive about showing it as to be unwilling to ask your way out of it is bad enough. But far worse than this is it when it allies itself with vanity. When you are asked something which you do not know say, "I will look it up," if you are capable of doing so; if not, say, "I do not know," and be done with it, but do not weary the soul of your interrogator by trying to conceal your ignorance and evading the question.

At the present time, and the writer has definite knowledge of what he is saying, young men in all parts of the country are constructing electrical apparatus. It is not saying too much to assert that a corps of electrical engineers, a sort of militia of the science, are drilling on all sides of us. In old times a young man given to such experimenting would ask the wildest questions about electrical things, but recently a very marked change has come. Definite information is now wanted. A dynamo is to be built for given ampèrage and voltage, and any questions about it refer to definite figures. In old times the question would be, how to build a dynamo for experimental purposes—as if that meant anything. Now the questions are, how to wind it for a given potential, and what its ampèrage will be.

Good work is being done. Many of the young men thus occupied are unable to go to college, and are, of course, at a disadvantage, if they adopt electrical engineering as a profession. But they have at

least the satisfaction of feeling that the profession is constantly widening, that there will be more and more positions, and that any success which they do attain will be deserved. It is for such young men that one's interest is most excited, for they will in times to come be the backbone of the profession, if they work up from the ranks.

Ruskin holds that there are two faults which are fatal to the character—idleness and cruelty. What we have to say here need not touch on the evils of cruelty. The highest aims of science are beneficent, and electricity is employed to alleviate the troubles of life. But idleness—that is the deadly sin of the professions.

Idleness commits all crimes—it murders, steals and lies. The idle electrician, not heeding details of his work, is the cause of a leak in a distribution plant, and a man is shocked to death, which is murder. It steals. An engineer is too idle to calculate out dimensions of everything in an electric plant; too small a boiler is bought, which has to be replaced at heavy expense by another. The loss to the electric works' owners represents the steal. It lies. A dynamo is to be calculated. A rough instead of an accurate computation is made, and the dynamo falls short. The lie here is measured in deficiency of volts or of ampères. Its criminality is measured by the monetary loss incurred.

Every bit of careless measurement executed in

the laboratory, considered in this light, involves a lie and a probable theft.

The one bit of ethics that applies to professional life is really all of ethics—it is conscientiousness. Be conscientious. Do not be guided in your work by the motive of honesty alone. Go a step beyond this and be more than honest—be the superlative of honest, be honorable. Let your conscience give you a diploma of self-approval that will outweigh any college degree.

Another quality is to be looked for—persistence. It is one thing to read in a book short directions for making an induction coil, but try it. Wind your secondary out of No. 36 wire, which breaks if you look at it; keep shellacking it and testing its continuity layer by layer, and, when done, see if energy and interest enough is left to finish the coil. You make special arrangements at your school to study chemistry or physics. A week or a month suffices to make you weary of your task. Does this indicate a suitable character to build an engineer on?

It is well that there is some basis for judging of character and of adaptability for a professional life, for it is sad to see a young man without taste for the profession trying to struggle along in company not suited to him. Indolence, want of persistence, natural selection of the easy and rejection of the difficult things encountered in study indicate qualities which are fatal.

Do not then attempt to enter ranks captained by such men as Sir William Thomson, Elihu Thompson, Brush and Tesla, without letting the dignity of the company be reflected from yourself. If not patient and persevering, if not naturally inclined towards mathematics, do not try to become a member of the profession. A college training to some extent compensates even for the want of natural aptitude,—but you will have to compete with men of high natural aptitude supplemented by the best college education.

This much will suffice for the general aspect of the subject. If a young man is a natural observer of everything, if he is of open nature, willing to impart knowledge as well as to receive it, and of mechanical and mathematical tastes, he may feel fitted to begin work in the profession of electrician. He must be industrious and without dread of work It is easy to profess to be so, but it is not so easy to answer to expectations in this regard. The only way to know whether a man is industrious or not is to try him, and there is nothing better than mathematics as a test-object. In modern science mathematics are everything, and reasonable familiarity with them is essential.

This gives a reason for plunging at once into our subject and speaking of mathematics and of their place in the course of study to be followed.

CHAPTER II.

MATHEMATICS.

ARITHMETIC—PRACTICE AFFORDED IN MECHANICS—POWERS OF TEN AND FRACTIONAL EXPONENTS—LOGARITHMS—ALGEBRA — GEOMETRY—TRIGONOMETRY—MENSURATION—OHM'S LAW—MATHEMATICS OF CHEMISTRY—ANALYTICAL GEOMETRY—CALCULUS—CONCLUSION.

What advice can be given about the dreaded mathematics? Edison, working up from a train-boy to his present position, claims to be no mathematician. You will do well enough if you get as high as he is,—so your first care may be to follow his example in one respect and let mathematics alone. Reparation will follow such a course, for you certainly will not follow his example in anything else if you start with such principles. Do you not suppose that Faraday envied J. Clerk Maxwell when he went to him for mathematics to elucidate his discoveries? Read Maxwell's life and realize that he laid the mathematical basis of much of modern electricity, and see if you are not cured of your distaste for mathematics.

Dislike for mathematics, like specialized dislikes in general, is usually a form of laziness.

The opening question given above is easily answered: the advice to be given is to study mathematics or drop electricity. The further you go in mathematics, the better, but here also go slowly.

Arithmetic you say you know. Well, before going further, review your old school books and get your arithmetic once more at your fingers' ends. Then start algebra. If you think it too hard, try as an experiment to add a, b and c together by algebra, and 7, 8 and 9 together by arithmetic, and see whether algebra is not sometimes easier than its sister science. In algebra go through simple equations before you take up physics.

Henceforward you will have practice in arithmetic and algebra in your other studies. In physics the change from one thermometric scale to another, problems in falling bodies, problems in inertia, mechanical powers and the like will exercise you in arithmetic and in elementary algebra.

There will be a reciprocation. The physics or mechanics you are studying will take on a new meaning, and at the same time your familiarity with your mathematics will increase.

Perhaps the reader has gone through calculus, and deems this very elementary. If our book throughout can but appear equally simple, its end will have been achieved. And many a college graduate, who has

passed in calculus, would fail sadly in deducing the law of falling bodies, though only simple arithmetic is involved in it. So do not criticise this book for not going far enough, exalted reader; but feeling that you have gone far beyond us in mathematics, pick out half a dozen elementary propositions in physics and see if you can prove them.

To return to our student of arithmetic and elementary algebra. He will note two peculiarities as he advances into electrical physics, and as he takes up the theory of dimensions of physical units.

One of these is the use of powers of ten. Instead of saying that a volt is 100,000,000 electro magnetic units in value, we say that it is 10^8 such units, and instead of calling v, the velocity of propagation of ether waves, 30,000,000,000 *cm.*, we may express it in powers of ten, as being 3×10^{10} *cm.*, and v^2 may be expressed in full as 900,000,000,000,000,000,000 *cm.*, or in powers of ten, as 9×10^{20} *cm.* The more compact method is certainly in every way superior, and you must learn how to calculate in powers of ten. Five minutes' study tells you how to do it—perhaps five hours or five months will be required to enable you to use without slip the results of the five minutes' study. So practice hard upon powers of ten, and never let a calculation involving them pass without doing it over yourself.*

The other peculiarity is used in dimensions. It is

*See "Arithmetic of Electricity," page 118.

the use of fractional exponents. This is very simple—but try how many of your acquaintances can tell you precisely what is meant by the exponent $\frac{3}{2}$ Taking the expression $11^{\frac{3}{2}}$, see if any of them can reduce it to its true value. You will discern an analogy with powers of ten, in the fact that the utility of both methods of calculation is greatest in operations of multiplication and division of identical symbols or of numbers in general. So as regards operations with fractional exponents you must learn how to multiply and divide any numbers or any identical symbols followed by fractional exponents. Multiplication is done by adding the exponents, as if they were common fractions, reducing the sum to the lowest terms, and applying the new exponent to the original symbol. Thus $M^{\frac{3}{2}} \times M^{\frac{1}{2}}$ gives $M^{\frac{4}{2}}$, or M^2. For division you subtract in like manner the exponent of the divisor from that of the dividend. Nothing could be simpler, but practice it whenever it occurs, and see if you can deduce by simple inspection the dimensions L T of resistance from potential difference $M^{\frac{1}{2}}\ L^{\frac{3}{2}}/T^2$ and current intensity $M^{\frac{1}{2}}\ L^{\frac{1}{2}}/T$, by dividing one by the other.

Logarithms should next be taken up, and if you can persuade yourself to do it, study their theory in your algebra. But learn well how to use them, for after all they are an instrument for your purposes—their theory does not immediately concern you. Make a point of using them frequently. If you do

not think them a means of facilitating calculation, if they seem to you merely an additional load, try to extract the fifth root of a number without using logarithms, and then in a couple of minutes do it by logarithms, and see which is the easier.

Learn thoroughly how to determine the characteristics of your logarithms. Do not leave them for a subject of guess work, or entire omission, but always put them in, whether needed or not. It is a very good habit to fall into.

Now you can go on in algebra as far as you choose —the further, the better. Skip nothing. The apparently or probably useless portions worked out will give you the best possible practice. When reasonably familiar with equations and logarithms, you have got your tools for attacking much of your subject.

Even in the beginning of algebra there is matter that is not applicable directly to your work. Such are the least common multiple and the greatest common divisor. It is better not to skip them. It is not merely rules of algebra that are to be learned, but familiarity with its operations is necessary, and this is best acquired by taking in everything as you progress in its study.

Of geometry a great deal is not directly useful. Indeed geometry, as far as the proofs of propositions are concerned, has direct application in very little work of any kind. It tells the why and wherefore of things, and gives the proofs of certain propositions;

but what is really of most practical use is the proposition itself—not the proof of it. Thus you may very contentedly go on calculating the area of triangles and the volume of pyramids, without troubling yourself about the proof of the rules you use, which proofs you may find in plane and solid geometry respectively.

There is one proposition you should be very familiar with and which you should put to frequent use by way of practice. This is the rule of the square of the hypothenuse—the famous *pons asinorum*, or "bridge of asses." The areas of triangles and similar things come under practical geometry, or, more strictly speaking, under mensuration, which you should also know.

Trigonometry must be studied so as to understand the functions of an arc, the sine, cosine and others. It is not necessary for the solution of triangles to be learned, but the functions must be thoroughly mastered. This will be a very small affair. But it would be excellent practice to solve a few triangles, just to get practice in logarithms and logarithmic functions. How to express one function in terms of the others and of the radius must be worked up, which really amounts to little more than the solution of right-angled triangles.

Mensuration must be learned, and as applied to ordinary cases it is very simple. It will be very advantageous to learn by heart a dozen good rules,

such as those giving the area of a circle, the superficies of a sphere, the volume of the same, the volume of a cylinder and the like. Then come the most convenient ratios of mensuration, such as contained in the statement that symmetrical surfaces vary in area as the squares of their similar linear parts or functions. There are two or three of these which should be thoroughly learned and practiced upon.

There is in electricity proper one little bit of mathematics which should be treated here specially. It is a simple algebraic formula of only three quantities, but the changes are rung on it *ad infinitum.* This is Ohm's law. It has never been deduced, and is based entirely on experimental proof. It should be practiced with in all ways. Three principal forms can be given it, and it can also be expressed by proportions of several kinds, as thus, the current varies directly with the electro-motive force and indirectly with the resistance. This embodies two proportions. Practice with Ohm's law should include operations with such proportional or ratio statements of it as the one given above.

You may also work up the mathematics of chemistry, mention of which is made under chemistry. But for the electrician it is better to treat chemistry as a whole, and to keep its mathematics with itself, and not take them up separately. The study of analytical geometry, of calculus and of the higher

mathematics in general may be postponed. They should be a part of one's equipment, but the practical, self-educated man will have to omit any exhaustive study of them in his earlier work, unless he has a very strong bent towards the exact sciences. Of course the college graduate will have gone through them, but even he, in many cases, will have but an imperfect acquaintance with calculus.

But analytical geometry must be attacked to a certain extent, comparable to the case of trigonometry as we have cited it. Just as the functions of an arc must be understood, so must the method of locating points in analytical geometry be understood. For every characteristic curve, and there are legions of them, of many types, from the curves of dynamos to the curves on the steam-engine indicator card, every such curve is drawn subject to the laws of descriptive geometry. The axes of ordinates and abscisses are the reference lines. Usually rectangular co-ordinates are used, but in angular motion polar co-ordinates may come into use, so something should be known of them.

The above outline is open to severe criticism as giving a very meagre allowance of mathematics. Yet if the amount detailed is learned thoroughly, the electrician will do very well as far as ordinary work is concerned. Mathematics are something like history—they cannot be learned from epitomes or abridgments. So it would be better for the aspir-

ant to go much further than we have indicated—to go through the whole of a text-book on algebra, and to work up analytical geometry and calculus. It may be feared that this recommendation will bear but little fruit.

Edison, with his avowed ignorance of mathematics, Faraday applying to Clerk Maxwell to work up the mathematics of a subject for him,—such examples as these may comfort one. But there are very few of us who do not feel a longing for greater advances in the science, and no failing is more felt than one's deficiency in mathematics. So the student should do his best to get beyond the very elementary schedule given in these pages.

CHAPTER III.

Physics.

HEAT AND LIGHT—EXAMPLES OF APPLICATION OF PHYSICS — BAD PRACTICES IN DISTRIBUTION OF LIGHT—REFLECTION OF WASTED RAYS—ECONOMY OF THE INCANDESCENT LAMP—MECHANICS — VALUE OF DEFINITIONS — ENERGY — THEORY OF DIMENSIONS—METHODS OF STUDY—EXPERIMENTING—PHYSICS WITHOUT APPARATUS.

The physics of the present day differs from that of the last generation, as it has taken a more precise aspect, especially in its divisions, and has become of less general aspect. From the practical point of view it is not necessary for the electrician to study physics any more deeply than it is to be hoped that his natural inclinations would lead him to. But it would seem absurd for an engineer dealing with heat and light to know the physics of these two branches only and to be ignorant of the physics of sound. So we will assume that a good manual of physics will be read from beginning to end by our student. Of special importance he should re-read and study light and heat, for much of his future work may involve the utilization of heat energy and the

dispensing of light energy. He should know how to conduct photometric observations, and understand the principles so well as to be able to improvise a shadow photometer from a sheet of paper and a ruler or walking-stick.

As he will be concerned with the economical supply of light, he should know something of the relative transparency of glass. After expending many watts of energy on an arc lamp or fifty watts on an incandescent lamp, let his studies in this direction teach him the absurdity, except for special purposes of using an opaline globe or a frosted bulb, involving a loss of fifty to eighty per cent. of his energy.

When the arc light was first introduced, one of the sapient ways of producing an approximation to evenness of light consisted in placing the lamps high in air, 250 feet perhaps above the earth's surface. The student from his physics can learn how enormous was the waste of light in this case, the intensity of the illumination varying inversely with the square of the distance. He will see the importance on account of the same law of the inverse squares of distributing arc lamps evenly and of not putting them in pairs or in groups. He will find attempts made to save the light which is radiated skywards, reflectors being used to reflect it back to the earth. He will from his physics learn how efficacious this plan is in each case. A white-painted surface will be found to be of little use; possibly he

may have a chance to try some better materials, such as totally reflecting prisms.

It is evident that knowledge of light may be very useful, and it is also evident that examples for criticism may be very easily found.

Measure the filament of an incandescent lamp and multiply it by ten; this will give you say 60 inches of filament. Does it not give one a sort of shock to realize that an entire horse-power is used up in keeping this little bit of material at a white heat? Think what it would cost to forge a horseshoe under similar economy. Is there not room for some brilliant genius to abolish with one stroke of invention and research the whole miserable instrumentality of incandescent lamps? Luminescence and other phases of the physics of light may give some clue to this.

You may yet be called upon to use and to supply heat energy as such. Dynamos are driven by some kind of heat engines. Our present sources of light, unfortunately, are simply hot solid matter. The working electrician is therefore very much concerned with the utilization of heat energy. He should understand its laws, the relation between heat and light, and between luminescence and incandescence, radiation, convection and conduction. The heating of a conductor by a current, electric welding, and many other engineering topics must be studied in the light of the physics of heat.

As to the other branches, they may be treated as objects of reading rather than of study.

Mechanics, often taken as a division of physics, is of direct importance. The conservation of energies, the relation of force to energy, the object of expressing energy in foot-pounds, why a unit essentially compound, such as pounds, is taken as a unit of force, which latter is a simple entity, the change of potential energy into kinetic energy, the change of one kind of potential energy into another, the doing of work by part of these changes and its absorbtion by the reciprocal parts, the apparent unreality of work thus defined,—all these things are in mechanics. No one is more constantly referring to work and energy than the electrician. Mechanics is a necessity for him.

It would even be well for him to write out different definitions of force, work and energy, and to learn by heart the best and most satisfactory ones he can find, so that without thinking he can give out the definitions. In any science it is excellent to have stepping-stones, or points of departure of fixed nature, and such could be given by the definitions above suggested. You may easily add more to them.

You will nowhere have a better chance to learn the value of a good definition, and also its rarity, than in physics and mechanics.

Take the case of a company selling light by the lamp-hour. Calculate how such a company would be affected by the introduction of a low resistance motor

in circuit with a number of lamps. Mechanics, giving the relations of energies, gives the basis for the solution. How the introduction of resistance coils may save a battery from running down and at the same time may waste energy, how every foot of a conductor is a seat of energy, how the energy in each foot of the conductor may be ascertained, the waste of energy incident to the necessary use of a resistance in circuit with a constant potential arc lamp,—all such topics relate to the important doctrine of the conservation of energy, and, while they are electrical in aspect, are actually questions of mechanics.

You should learn mechanics thoroughly, and it is better in mechanics especially to learn a little very well, rather than to get a mere reading acquaintance with a great deal. The learning a little thoroughly is not so simple as it may seem. You should learn to work with $\frac{1}{2}mv^2$, as with a most familiar character. The little well learned will be the incentive to more reading, and the foundation it gives will make such reading far more profitable than it would otherwise be.

You may have a taste for mathematics, which expression often indicates that in reality the possessor of such alleged taste is not too lazy to study. If you have this quality, whether it takes the form of taste or of industry, the theory of dimensions will greatly help you in studying mechanics. By the use

of the wonderfully ingenious theory of dimensions of physical quantities you can trace the relationship of all the units to each other.

You will find the mathematical treatment now underlying all physics, and dimensions you will see used perhaps even more in the physics of electricity than in mechanics proper. In other branches of the science they are less used than in these two.

We have used the term physics of electricity, indicating thereby the treatment of its theory as a whole without restriction to one part of the science. Most books on electricity treat some specific branch. This remark may serve to introduce a suggestion that the manuals of physics give a treatment of the subject that will be of value in presenting a unitary view of the subject as a whole. Electricity, as treated in Daniell's "Physics," may be read and studied with benefit by any one.

How shall physics be studied? It depends on the student and teacher, if there is one. It may be studied by experiment on the inductive system. This is the popular way at present, and for a very good reason is accepted as the best method. The very good reason is the following: The trouble with the rising generation is that they have not sufficient acquaintance with or realization of the real or concrete world. To them everything in physics is apt to appear as an abstraction. When studying heat it is hardly too much to say that conduction of

heat does not present itself to them as the same thing that makes one drop a poker that has been left in the fire. Being in the realms of science and studied as such, the heat of the books of physics, they think, must be something peculiar and unfamiliar. But it is not—it is the same thing as we meet in every-day life.

By teaching the science inductively and letting the experiments tell the laws, and by letting the pupils perform the experiments themselves, they lose this abstract conception of physics. Thus taught it becomes a real every-day thing.

If you examine some of the newer school manuals, this treatment will be very conspicuous in it. The deduction might seem to be that those for whom this book is written should do the same—should study physics inductively and by experiment.

But it is fair to assume that those who honor this little work by perusing it, and making it of use to them in their life's work, have a special aptitude for science. They will probably have always handled tools, and will not be apt to take so abstract a view of things. And then the question of time comes in. It takes many long hours to work up physics by experiment. If the time can be afforded, try experiments in physics as you go along. The ground can be covered by the use of very little apparatus. "Physics without apparatus" has now been quite highly developed. If the time is not at your dis-

posal, never mind. You can learn physics by study and reading alone.

One reason for rather discouraging too many experiments in physics is that work in construction may be more practically applied to electric apparatus. Yet here the error of being too practical may be fallen into. A one-sided man, we have said before, is imperfect. Some few experiments can be tried as you read and study physics, and they will take the guise of recreation. In sound the experiments in loops and nodes and harmonic vibration may be performed very nicely with a wire stretched across a table over two blocks of wood as bridges. Vibrating flames may be observed with a small looking-glass twisted back and forth in the hand. A square of glass held down on a spool by the thumb will serve for a Chladni plate. In heat the simplest possible arrangements will serve to show the expansion of solids, liquids and gases. A blacksmith putting on a wagon-tire shows the first of these. In light, shadow photometry may be worked up with considerable advantage as being of direct applicability to electrical work. A few hours will be well spent in making a skeleton of experiments to carry your living body of physics. But the bulk of physics you must get from the books.

Do not try to cut mathematics out of it. Wherever a formula is given, remorselessly hunt it down and work it out to the last point. Keep dimensions in

mind, and over and over again go through their evolution. Then, when you reach electricity, you will feel at home. It will appear how a watt is a unit of rate of energy, and the relation of electrical to mechanical units will be made clear; without dimensions you can never see how these relations are deduced. In after-life you may forget the exact deduction of dimensions, but enough will stick to give electrical and mechanical units a meaning which they would never otherwise acquire.

CHAPTER IV.

CHEMISTRY.

DIFFICULTIES OF EXPERIMENTING — THE COAL-FIRE AND THE PLANT—THE REACTION OF THE COAL-FIRE—ITS EQUATION AND WHAT IT TELLS—EQUATIONS THE SHORT-HAND OF CHEMISTRY—STOICHIOMETRY — EXPERIMENTS — PRECAUTIONS —BATTERY CHEMICALS — THERMO-CHEMISTRY—CHEMICAL RECREATIONS—BOOKS—OUTLINES OF A CHEMICAL COURSE—HOW TO READ—VALUE OF A TEACHER.

There are a number of books treating of simple experiments in physics. The field in this department is pretty well covered. Every now and then the inquiry comes up for a book devoted to simple chemical experiments. This book has not yet been written—at least a satisfactory one has not. The reason is not hard to find. Chemistry is a science that admits of no trifling. Simple experiments in it are very attractive, but a series of such soon loses variety, and they become monotonous to all but the real student. An electrician should know the theory

of chemistry, as his science is closely linked therewith, but unfortunately the theory of chemistry, unfixed in the mind by any experimental work, seems very unreal and abstract.

Chemical work can often be carried on at school to a point where some idea may be formed of what qualities a gas may present, of what a reaction between two substances is, of the actions of acids on metals. If the experimenter, knowing nothing of chemistry, begins to experiment without supervision, it is merely a question of time when he will blow himself up.

This makes studying chemistry by experiment at least of doubtful expediency if it has to be done alone. But can chemical operations be seen otherwise? They can be seen everywhere. One of the highest affinities in all chemistry is being constantly satisfied in a violent reaction seen in every house. The plant, with intense chemical force, given it by the sun's actinic rays, is doing the reverse and undoing the combination silently and without violent exhibition of its powers. Are not these chemical experiments available for purposes of study?

For what takes place in the hard coal-fire, which is the first reaction spoken of? The coal is principally carbon, one of the elements, and carbon has an intense affinity for another element, oxygen. About one-fifth of the air is oxygen. In spite of its affinity for oxygen, carbon will not unite therewith below a

red-heat; when heated in the air, it combines with oxygen. Chemical energy is satisfied or disappears, and heat and light energy are produced. The coal, in other words, burns. Now take on faith two statements. Twelve pounds of coal combine with thirty-two pounds of oxygen. This ratio, for complete combustion, always and invariably holds. Next, if the carbon and oxygen were both in the gaseous state, it would be found that the carbon would have half the volume of the oxygen. As a species of chemical short-hand, twelve units by weight of carbon are indicated by C. Sixteen parts by weight of oxygen are indicated by O. These same symbols indicate equal volumes of the elements in question when in the gaseous state. Now write as follows:

$$C+2O=CO_2.$$

This says that one volume (in the gaseous state) of carbon weighing twelve units combines with two volumes (in the gaseous state) of oxygen weighing ($2\times16=32$) thirty-two units. The product is ($12+32=44$) forty-four units by weight of another substance called carbon dioxide, or, more generally, carbonic acid gas. It also tells a chemist that the volume of the new gas is equal to that of the oxygen.

This is one of the dreaded chemical reactions that seem such a mystery to many. They are really a great convenience; the eight characters of the equation tell as much as can be told in as many lines of

type, and the common coal-fire gives us the chemical reaction expressed in the equation. The prospective engineer should give himself a thorough course of chemical equations, and should work up the proportions they express. This species of calculation or chemical arithmetic is given in the textbooks and should be learned, or at least the underlying theory outlined above should be well mastered.

Too much is not asked in this. A person with the least aptitude for mathematics will find no trouble in it. One fond of mathematics will take much the same interest in stoichiometry, as the arithmetic of chemistry is termed, as a chess-player does in chess problems.

It will be easy to perform a few experiments in safety by avoiding the use of certain chemicals, such as strong acids, and by avoiding certain causes of explosion. But it would be very hard to adequately state in words the various precautions which a practiced chemist instinctively takes. Even in heating a liquid in a test-tube he never points its opening at himself or at others for fear the contents may spurt out. In adding a chemical to it he follows the same rule. If two liquids of different specific gravities are in the tube, he always shakes them up thoroughly before heating, to guard against explosive ebullition. It is thus all through chemistry. Little details of manipulation distinguish the good from the bad operator. The electrical engineer cannot well afford

time to learn all these minutiæ. If he has the time and facilities, he will of course try to learn as much as possible.

But let him study the formulæ of his own chemicals. If he is using gravity cells, he must not be content to throw in what to him is nothing but a "blue-stone." Let him know it as cupric sulphate; let him learn its formula $CuSO_4$, $5H_2O$, and find what each symbol stands for, and for what relative weight of its respective element. Distinguish betweeen this compound and cupric oxide, CuO, of the Lalande-Chaperon couple. Dissolve some $CuSO_4, 5H_2O$ in water, immerse a piece of polished iron in it, and see the deposit of copper, and realize that some of the iron has stepped into the copper's place, and has formed one of the iron sulphates.

The many batteries in use will give a good field for studying chemistry, and the mere handling of a chemical salt, such as sal ammoniac (ammonium chloride), if its formula and constitution are made to go with it in the mind, will give to chemistry the desired reality.

Next comes thermo-chemistry, which is simply the laws of the relations of chemical change to energy. While nothing is more interesting than the working out of the voltage corresponding to chemical changes, such is generally rather an ornamental or perhaps accessory branch of the study. The general principles of thermo-chemistry, which may be stated

in very few words, should certainly be known. To give the aspect of unity, it would seem preferable to take thermo-chemistry as a part of the conservation of energy. The engineer should have very fixed ideas on this subject of the conservation of energy, for his profession is concerned almost entirely in converting one into another and in distributing the energy he has shaped. Thermo-chemistry relates to the heat units produced by coal, the watts produced by a battery, and the voltage developed therein. It is clear that acquaintance with it should be a part of his stock of knowledge.

What is said in relation to chemistry may be taken as implying that the engineer need not go very deeply into this science, and such is the most practical view of the case. Chemical formulæ find no part in the every-day work of the electrician. But none the less should as much of chemistry as is outlined above be studied. It is depressing to one's moral nature to think of a presumable electrician using primary and storage batteries, working with currents whose units are based on voltametric work, yet knowing nothing of chemistry.

There is, however, a chemistry without apparatus, which can be used as a species of instructive recreation. A number of experiments in it can be traced up in the literature of the science. Thus roll or twist a strip of paper into an allumette or gas-lighter. Holding its large end pinched between the

finger and thumb, and holding it pointing downwards, light the lower end. As the flame works its way up towards the hand, a black cinder is left nearly of the shape of the allumette. The flame is producing destructive distillation as well as combustion of the paper. A white smoke which is produced by the distillation issues from the lower end. Now apply a match to the lower end, and you can light the escaping gaseous and other matter escaping therefrom just as you can light gas at a gas-burner.

This gives an excellent illustration of the action of heat on organic matter and of combustion. Nothing could be simpler or more demonstrative. This is chemistry without apparatus.

Again put some sodium bicarbonate, which is common baking soda, into a pickle bottle and pour on it some vinegar (acetic acid). It effervesces, and carbon dioxide gas is given off. Attach a match to a bit of wire, get the match burning well, and lower it into the bottle. The gas extinguishes it as effectually as would water. Try to pour some of the gas into a tumbler, as you pour water, and test its presence in the tumbler by the match experiment.

This again is chemistry without apparatus. Nothing in the laboratory could be more conclusive.

Write out the reaction for this experiment. Find the formulæ of acetic acid and of sodium bicarbonate,

and put them in the first member of the equation. When they react upon each other, sodium acetate, water and carbon dioxide gas are produced. Put these in the second member, and then see if your equation balances—that is to say, see if the same symbols and if the same number of each appear on both sides of the equality sign.

The equation for destructive distillation of paper cannot well be written out, because the reaction varies and is imperfectly known.

The actions of acids and alkalies on test-paper or vegetable colors can be easily tried with litmus paper or red cabbage infusion. Use vinegar for the acid, and ammonia for the alkali. A few cents' worth of common hydrochloric acid will give more satisfaction in all these experiments than will vinegar.

You will, if you undertake to work up this study, infallibly procure a little apparatus, if it is only a few test-tubes. But it is not advisable for you to go too deeply into chemistry unless you can have a good teacher and plenty of time at your disposal. A few experiments made as above suggested, with their reactions studied and understood, will give an idea of a science to which years may readily be devoted.

The following may be taken as an abstract of the ground which should be covered. The great object of the student should be to grasp the general theory of the science. There is little use for him to know the atomic weights by heart,—there is every reason

for him to understand just what an atomic weight is. This, then, is presented as a schedule:

Three states of matter, solid, liquid, gaseous.

What an element is—the elements in general.

What a compound substance is—the combination of elements.

The divisions of elements—the atom and molecule.

The compound molecule.

The law of atomic weights.

Relation of the law of atomic weights to chemical combinations—this includes *a*, the constancy of composition; *b*, the law of multiples; *c*, the law of equivalents.

Law of combination by volumes in the gaseous state (Avogadro's Law).

Chemical symbols—their full meaning and their use in equations and formulæ.

Atomicity—the bonds or saturating power of elements; monads, dyads, etc.

Chemical affinity a source of work; hence unsatisfied chemical affinity a form of potential energy; by satisfying chemical affinity kinetic energy is produced.

Relations of heat to chemical affinity.

Electrolysis or decomposition of chemical compounds by electricity.

This much the student should work up as thoroughly as possible with a good text-book. A pad

and pencil should be at his side, and symbols used at every step where possible. When this ground has been covered even cursorily, and it is best to go over it all as well as possible, three or four of the elements should be taken up, one by one. Oxygen, hydrogen, carbon and zinc would be good ones. These should be studied with constant reference to the schedule outlined above, the idea being to make each element illustrate the general philosophy of chemistry. This philosophy the schedule given above is designed to cover.

The elements studied may be extended. It will be of inestimable advantage if a few weeks or if a few hours a week for a few weeks can be given to practical work. It is possible that it can be done alone, but for personal safety, as well as for much greater efficiency, it is most desirable that an instructor should be employed. In our high schools, teachers are always to be found capable of giving excellent chemical instruction. Some arrangement can probably be made with some of these.

In studying the philosophy of chemistry, as we have termed it, much must be taken on faith, and it will seem dry and abstract, and perhaps impossible to remember. This is often the case with things involving a new order of thought. But two weeks' work following good study will work a wonderful change, and the science will crystallize into shape in the mind, and the symmetry of it will clearly appear.

Chemical work is divided into two branches, qualitative and quantitative. The first treats of the qualities of things, such as the various properties of the elements, the color, specific gravity and general nature of each, and of the salts of reactions and of all substances. Quantitative work refers to the quantities that enter into reactions and to the determination of such weights and volumes. Chemistry restricted to one or the other branch is but half expressed or learned, as the case may be. The quantitative relations expressed by an equation have been just brought forward. These relations should be practically studied, and a week in a laboratory will give some idea of them.

If the study is abandoned before the full meaning of an equation is reached, a great error will have been made. The relations expressed by an equation are quantitative as well as qualitative, as has been shown—the symbol Zn, for instance, means not only zinc, but sixty-five parts by weight of zinc, the "part" being the relative unit, which happens to be the atomic weight of hydrogen. Now a person may learn all this, and learn the meaning of equations, but he will miss the most perfect grasp of it, if he does no quantitative work. The conception of what a precipitate is is easy to acquire. If such be filtered out, washed and weighed, if by stoichiometry and equations the weight is made to tell its full story, a quantitative determination has been made, and the

student at once perceives the idea of relative weights of atoms. The Edison chemical meter, the silver voltameter, the operations of the electroplating bath, the consumption of definitely and unvaryingly related parts of zinc and copper sulphate in a Daniell cell,—all such are understood in a new light.

So our concluding advice is for the student to do a little quantitative work, to arrange with a chemical friend or even with a pharmacist for a little instruction and for the use of the creator of modern chemistry and the present arbiter of all its operations—the balance. For in giving us balances which weigh down to one-twentieth of a milligram, the Beckers and other balance-makers have made great and important contributions to the development of chemistry.

CHAPTER V.

Electricity At Home.

ELECTRICAL EXPERIMENTS AT HOME—MODERN PHYSICS TAUGHT QUANTITATIVELY—SIMPLE APPLIANCES NOW USED—MAKING ELECTRICAL APPARATUS AT HOME—THE WHEATSTONE BRIDGE—GALVANOMETER RESISTANCE COILS—CURRENT STRENGTH—BATTERIES—STATIC ELECTRICITY — ELECTROMETERS — CONDENSERS—AMPÈRE'S LAW—MAGNETISM.

What direction should work at home take in the electrical line ? It is by no means necessary that much should be done, but it is hard to imagine any one with a taste for the science who will not work in it during spare moments. There is also this to be said, that before entering into any engagement at an electrical works or station his time will generally be more at the student's disposal than afterwards. This is the period in which to familiarize himself with electrical construction. Fortunately much can be done with the simplest appliances. The work at home, or much of it, should take the direction of electrical measurements.

Electricity has been defined as the science of measurement. This definition is correct, but not specific enough, for physics in general may be identically defined. To see how the science of physics is now taught, the Harvard schedule of work to be done before admission to the college course may be consulted. It is full of measurements—nearly everything in it refers to weighing or measuring or determination of strain. The old system of simple demonstration of laws has become antiquated.

The same applies to electricity,—in the modern science we work by volts, ampères, and other units. A constant appeal to measurement underlies all operations.

From the Harvard schedule another hint as to modern methods of teaching may be taken. The work prescribed in it is all done with the simplest appliances. The strength of materials and factors of stress are determined with ordinary spring balances. As C. V. Boys expresses it :

"In these days we are all too apt to depart from the simple ways of our fathers, and, instead of following them, to fall down and worship the brazen image which the instrument-maker hath set up."

Our student may have seen the beautiful apparatus in an electrical dealers' store. The meter or shorter bridges, the boxes of resistance coils, the tangent galvanometers,—all vie with each other in elegance of construction. If he had but the money, here is where he would spend it. But he can do bet-

ter than that—let him make his own apparatus. He can make it accurately enough for the end in view, which end is to learn something about electrical measurements and incidentally to acquire practical experience in electrical construction. Again the true theory of instruction is to begin at the bottom, and to start with the simplest things. His first measurements may be of the "spring balance" order and made with the crudest possible apparatus.

Let him study out the familiar diamond of the Wheatstone bridge and see how simple is the theory. Imagine the four resistances to be four pipes of different sizes, and see if water would not follow the same law. Next on a board he may lay out the connections. One standard resistance is required, which can be taken arbitrarily. An electric-light carbon with caps of lead cast on the ends to give facilities for good connections will answer for this. A galvanometer is needed. A compass resting within a coil of wire will suffice. The proportionate resistances of two elements of the bridge must be known. These he can deduce from their relative lengths. Connecting his battery, he can in a few minutes determine how many times the resistance of the carbon is contained in the unknown wire or conductor whose resistance he is measuring.

The above description suggests a meter-bridge, as it is popularly called, and this, as the simplest, is, perhaps, the best to start with.

The first thing which the student will find is that his galvanometer is entirely unsatisfactory. A very delicate one is essential. He will feel the want of a standard also, for the true resistance of his carbon is unknown. But his extemporized galvanometer will probably be his first trouble. Here will be a temptation to construct a good one. Next may come the construction of a standard resistance coil. He can borrow a one or two ohm coil, and using his galvanometer and Wheatstone bridge, can make a resistance coil for himself.

When he gets this far, he finds that his bridge is a poor-looking affair. So he gets a hard-wood board and makes an accurate meter or half-meter bridge. He has read up on the subject, and what he now reads is more than mere words to him. He studies the proportions required for accuracy, the expedient of increasing the length of the proportional wire, so as to work at its most sensitive portion, and learns the range of work which his one resistance coil can adequately cover. The conditions of accurate working make the range, with the one resistance coil, very limited. He needs more coils.

His accurate bridge, with sensitive galvanometer, gives him the facilities for making new coils of greater resistance, and his set increases in extent. He reads up the subject of coils, notes that they must be wound non-inductively, studies the best ways of securing insulation, and the best way of providing end-contacts.

He will now wish to measure current strength, for doing which he will build a tangent galvanometer. If he works with a battery, he will wish to obtain its factors. This involves the determination of potential. If his tangent galvanometer is wound finely enough, he can determine potential directly, using a Daniell couple for standard; or he can use some of the other methods described in the books, such as Poggendorff's method.

Current measurement may also be done by voltameters. If a balance is at hand, a copper or silver voltameter may be used. A very practical experiment would be to make a zinc voltameter, such as the Edison electric meter. This electrolytic work is of great utility, and for it the student could make some kind of a balance which would give approximate results.

A good galvanometer being a necessity, some work should be devoted to making it, and, perhaps, all things considered, a tangent instrument with high and low resistance circuits would be the best. This may have its needle suspended by a filament, and may carry a convex mirror, so as to give practice in the reflecting principle. Next a standard battery will be needed, for which the Daniell combination may be used. Now the student may determine voltages, having at hand the essentials.

Wheatstone bridge work has already been spoken of, and will be the most important in every way of

the operations so far described, because in it we are brought into contact with the most used measurement of the electrician. Such a book as Ayrton's "Practical Electricity" will be found useful in working with a bridge, as it gives the practical points which conduce to accuracy.

The above is a mere hint of how our student can practice electrical measurement and construction. Every boy is apt to have made his own batteries. These are very easy to construct now. Discarded bits of electric-light carbon are doing service all over the land in amateur batteries, and even in those sold in the stores. It is probable that the student will make a dynamo or mechanical generator. One thing will lead to another, and soon he will have a concrete idea of electricity as far as his knowledge goes. This means that a volt or an ohm will no longer be to him shadows and names only—*magnorum nominum umbræ*,—but will mean something actual and real.

Accepting the convenient division of the science into static electricity, dynamic electricity and magnetism, the suggestion would be not to neglect the older sister, static electricity, and at the least to go as far in it as can conveniently be done without the use of an electric influence machine. But if an influence machine can be borrowed, procured or constructed, the student will perceive the utility of studying its action and of performing experiments

with it. Such a machine places at command an unlimited supply of very high-tension electricity, and enables very showy experiments to be performed.

With it the Leyden jar can be investigated—its rapid silent discharge by air convection when it is connected to a quantity of points, its residual charge, and alternative paths of discharge. In the latter line of work it would be advisable to go over some of Oliver Lodge's experiments—those in which he worked upon the protection of buildings from lightning. Reports of his lectures are accessible, and his work was most interesting.

With plenty of high-tension electricity at command, electrical resonance can be studied, and at least some of Hertz's experiments can be worked up.

As regards quantitative work, something can be done in it. The student can construct a rough electrometer—something better than the old quadrant and pithball. This will enable him to measure electric tension, and to measure dielectric capacity. A balance of some sensibility can be easily made, so that a Thomson weight electrometer might be built and experimented with. This would be of double utility, as it brings us face to face with absolute measurements.

An introduction to torsion instruments might be made here by the building of a torsion electrometer of the quadrant type. With it again some measurements could be got—or at least an approach to quantitative results.

The construction of condensers might be taken up here, and, ultimately, if a good enough galvanometer is ever made, the determination of static charges, capacities and dielectric constants could be studied.

The laws of static charges, their concentration at the parts of conductors where the radius of curvature is smallest, and the escape of a charge from points give rise to a number of pretty experiments, which could easily be carried out with little expenditure of time or labor.

In magnetism the work must be prosecuted largely in full accordance with Ampère's law. This indicates the reaching the laws of the magnet through electro-magnetism. The conception of a magnetic circuit, the analogy between reluctance and resistance, between permeance and resistance, between permeability and specific resistance, must be well formulated, and lines of force must be mapped out to illustrate it by the use of iron filings. Nor must the student fail to note where the analogy fails—the resistance of an electric circuit having no reference to the current, while permeability of iron varies with the number of lines of force in a given cross-sectional area; air, on the other hand, holding an invariable permeability. In dynamo and motor construction the magnetic circuit is the very soul of the matter.

The relations between a magnet and a current

should be well worked out experimentally, so that any of the *memoria technica* given in the books should be at instant service. After test and verification by experiment the familiar man swimming with the current will have a new interest and will tell a better story than if he had only been studied theoretically and from books.

CHAPTER VI.

Mechanical Engineering.

GROUND COVERED BY MECHANICAL ENGINEERING—ITS PLACE IN ELECTRIC PRACTICE—MACHINES AND TOOLS—ENGINE TESTING—STRENGTH OF MATERIALS—MACHINERY—USE OF THE HANDS—EXTREMES IN PRACTICE—COLLEGE WORK IN PRACTICAL MECHANICS—MACHINE-SHOP WORK FOR THE STUDENT—OBSERVATION AND READING—FAULTY PRACTICE.

Mechanical engineering is a very comprehensive term. It covers so much ground and so much information that it may be regarded as the framework of an electrical education. Sir William Thomson holds that it forms by far the greater part of electrical engineering.

When, therefore, one undertakes to speak of mechanical engineering, it amounts to a recapitulation of a great part of such a book as the present one. An accomplished mechanical engineer can take hold of electrical work with very little special preparation or study. The student of electrical engineering may

reach his goal by means of mechanical engineering in great part, because mechanical engineering covers topics of great value to him.

The building of a dynamo involves considerations of mechanical engineering in the balancing of its armature when running as well as when motionless, in the construction of its journals with proper end-play, in its establishment on a proper foundation, and in other details of construction. The driving of a dynamo by belt or otherwise is a matter of mechanical engineering. The modern high-speed engines are triumphs in this branch, and they are extensively used in electric plants. Some of the finest examples of mechanical practice are seen in electric light and power stations now,—at one time it was far different. The use of rope transmission of power is excellently illustrated in some of them, while in the direct coupled engine and dynamo we find a compound machine, whose "better half" is certainly of the mechanical order.

Mechanical engineering covers the use of machines and tools, such as the lathe and planer. A competent engineer should be able to design, draw, and to a considerable extent construct a good steam-engine of modern type. Almost any mechanically qualified person can make some kind of an engine, but not many can execute the whole properly.

The testing of engines and boilers, including the use of the indicator, the correct interpretation of indi-

cator-cards, and the calculation of horse-power therefrom, the determination of boiler and engine efficiency, the calculations for thickness of boiler-shells, the proportioning of parts of boilers, the laying of lines of steam-pipe of capacity for specified work, are examples of the work of the mechanical engineer. His work may be defined as the practical work of mechanics.

The calculation of larger structures, such as bridges or roof-trusses, is also within his scope, but such work and the strength of building materials are usually considered as appertaining to civil engineering.

He is concerned with the strength of materials used in his processes. He cannot calculate a boiler without knowing the qualities of the metal of which it is to be made.

The knowledge of machinery in general comes within this branch. But the reader with any bent for electrical engineering need not have machinery recommended to him as an object of interest, for it must be this to him on account of his very nature. But as mechanical engineer he must do more than entertain himself. He must be a practical worker. In another portion of this book work in factories is treated. If the reader has no machine-tools of his own and no access to a shop, he must have in his mind a determination to sooner or later supply the deficiency in his studies thus incurred. He must

know something about tools practically. If he will study up a tool thoroughly, he can easily learn to work it. It would even be well for him, or better than nothing, to do work in a gas-fitter's shop, so as to get some idea of how pipe are fitted.

One object of this is evident. If he has to enter a manufacturing establishment in any capacity, knowledge of tools will stand him in excellent stead.

Another object to be gained is the use of the hands. An engineer should be able to employ these important members to good effect when called upon. In the courses in mechanical engineering given in our best colleges, every student is given a training in some branch or branches of machine-shop work. An intelligent person who can do one kind of such operations will have little trouble in taking up a new tool.

Therefore he who wishes to be an electrician should unquestionably be a mechanic. This may not in all cases mean that he must know how to run a giant planer to the best advantage, paring down the edge of thirty-inch armor-plate as if it were pine wood. He might not be a success in running a jewelers' lathe and in cutting out microscopic pinions. But in him there should be the capacity for doing such work if the time should come for him to perform it. An unwashed, oily workman, standing all day before a drill-press and drearily reaming out holes in castings where the iron falls in dust slowly

from the hole, who, when he goes to the lathe, centers his work on center-punch prickings, too lazy or too ignorant to drill a center-hole which will bear on the shoulders of the lathe-center and not on its point, may call himself a mechanic. But does not he yield to a man like the scientist Boys, who has evolved the quartz fibre as a suspension filament, who worked out the handling and manipulation of the almost invisible thread of rock-crystal, and who makes up his own apparatus as required? So, though you may have spent months in a dirty machine-shop, be chary about calling yourself a mechanic,—though you are at home with a lathe or a planer, you are not a mechanical engineer until you can work out and superintend their construction from the pig and bar.

If you wish to know how far a man may go in mechanical engineering, send for a catalogue of a college where the degree of mechanical engineer is given. You will be surprised at the range of the course, and you must not suppose that it is all books. The students put on overalls and work in the shop just as you do. Because their work is intelligently directed to the end of teaching them the most possible in the shortest time, you must not look down on it—rather recognize the luxury and good sense of it,—and if you are, from force of circumstances, plodding in a shop, feel that your long hours of labor will improve you more by their disciplining effect than

by simply enabling you to cut more inches of screw in a day than the apparently superficial student. Neither one should criticise the other,—let each do his best where he is, and feel that he is stepping on the lowest round of a ladder of unknown length.

So you must be a mechanical engineer. Now look over this book—take out everything that refers directly to electricity, and see if it will be much smaller.

It speaks of your natural qualifications—do not these bespeak a mechanical engineer? Chemistry, physics and mechanics are spoken of. These, too, apply to the education of the mechanical engineer. All of this section, all of the one devoted to drawing, much that is said about reading, about mathematics, steam engineering, etc.,—does not all this apply to the same profession? Therefore, when you are a mechanical engineer, your work is more than one-half done.

In your capacity of constructor you may have to design machinery. If you have studied up foundry work, you will have constantly in your mind the operation of the pattern-maker, and will, in your design, offer him as little difficulty as possible in making for your machinery patterns that will draw from the sand. If you are working with a galvanometer or electrometer and break the filament, you may have to replace it yourself. Here are the two opposite extremes of a mechanical constructor's work. You

will not be called on for both at the same time probably—of course you may be,—but the lesson is clear: Try to learn to use your hands and brain well. Be a mechanic in manipulation and in thought.

A good quantity of machine-shop work will be excellent for the student. If you have to work by the day, there will be a great disadvantage in the fact that you will have to work at a single machine, perhaps, with not even a chance of looking at another. But if you can run one, a few hours' practice will enable you to run another, so your time will be well spent.

Observe all machinery which you come across. Note the little details of construction of locomotives. Visit shops of all kinds—take sketches on paper—or, what is far better, take mental sketches of everything you see. And all the while read. In the proper place you will find a few mechanical books recommended. The object there is to make as short a list as is consistent with the purpose of this work; but you can amplify the list to any extent.

Since the purpose of this book has come up, recall one theme on which it has preached from the beginning—be thorough even at the expense of not going over much ground. If you are in a machine-shop and are to work on a lathe for six weeks, in that time learn all the mysteries of it. Learn how the pitch is changed—work out the different combinations of

gear-wheels—calculate what would happen were the feed-screw of a different pitch—note how the lathe is put together—see if you could run it for light planing—study out a method of working in it long pieces, too long to go between its centers. You will find that understanding one thing very well will help you to understand others.

Examine electrical line-work and in-door and out-door wiring, and see the numerous examples of clumsy mechanical work which meet the eye everywhere. The exclusion of converters from the interiors of buildings having come to be recognized as proper, the custom is established of placing them on window-sills and elsewhere on building fronts. Perhaps an unpainted board is fastened first in the neighborhood of the window, and on that the converter is placed. Wires are carried from the line to the converter and from the converter into the house. The whole arrangement of unpainted board, rusty converter case and weathered wires is unartistic in the general sense, it is true; but it is worse than this. It is unartistic in the technical sense, as it offends every instinct of a mechanic. The weather-worn arrangements with rusty nails adding their stains to the rest—galvanized iron being an unknown or forgotten luxury—is unmechanical. Can you not make up your mind that as a mechanical engineer you would attend to such details as these, and redeem alternating current lighting from its present reproach of hideousness?

This may seem too strongly put. Ten years from this time, when we look back on what was endured at the hands of electrical workmen, it will not seem so, for then the better era, it is to be hoped, will be inaugurated. The readers of this book may furnish recruits to the army who are to better these conditions.

In-doors we find the same indifference to details. Battens, unvarnished and ugly, are run everywhere, to carry wires. They are run right across a moulding, no attempt being made to follow the curves. If this is impossible with ordinary battens, as it is, it might be within the resources of the mechanical engineer to devise some neater way of crossing a moulding or cornice.

It is in the neglect of details that electric service has become so ugly in its carrying out. There is room for progress and improvement.

The details of engineering practice cover everything of the nature suggested above. The use of non-corrosive iron, galvanized or otherwise protected from rust where exposed to the weather, the painting or varnishing of wood-work, the neat and electrically perfect jointing of wires,—a multitude of things of this nature come under the cognizance of the mechanical engineer.

CHAPTER VII.

Drawing.

DRAWING A POOR RELIANCE BY ITSELF—ITS IMPORTANCE TO THE ENGINEER — FREE-HAND PRACTICE—SKETCHES IN NOTE-BOOKS OF PHYSICS OR CHEMISTRY—SHADE LINES—PEN OR PENCIL PRACTICE—DIMENSION SKETCHES—PROFILE PAPER—DESCRIPTIVE GEOMETRY — PERSPECTIVE —BLUE PRINTS—CARE OF INSTRUMENTS—CONVENTIONAL REPRESENTATIONS—CATALOGUES.

Business men have a theory that a really good book-keeper is apt to be so useful a man that he lives and dies a book-keeper, and is never anything else, so that it would seem to be the best plan in a certain sense not to learn book-keeping. Somewhat the same thing applies to mechanical drawing. It is well to understand it, and to be able to do good work with the T square and drawing-board, but such knowledge must be only an equipment, not a profession.

If drawing is your all, you will never leave the traces. If you do draw well, be sure you can do other things well also; for if you can draw and can

do nothing else, you might almost be advised to conceal the fact, lest you become a draughtsman for life.

Seriously speaking, drawing should be learned; not necessarily free-hand work, but certainly mechanical drawing. It is a great comfort to be able to produce a correct sketch of anything wanted, a sketch which will be good enough for a draughtsman or machinist to work from. A new dynamo or motor may be studied up on the drawing-board to great advantage. Even the working out of a simple matter of circuits is often much facilitated by drawing their diagram with rule and right-line pen, instead of making confused pencil sketches. It is possible, too, that you may wish to make memorandum sketches of ideas that occur to you, and the convenience of being able to do this for one's self is very great.

If an instrument is to be designed, it will be of pre-eminent service for the originator to be able to draw it for himself, for to be obliged to absolutely depend upon another to design for you is almost slavery. The very drawing of a new apparatus will give ideas concerning its construction.

Excellent practice in drawing consists in making a free-hand sketch of a machine, in quoting dimensions on the sketch, and in making from this a full mechanical drawing. It is quite conceivable that such operations might prove very useful in real life, for one might often desire a drawing of some par-

ticular thing, which could only be obtained in this way.

You know by this time that you have got to be a mechanical engineer, if you are to be an electrical engineer. Did you ever hear of one who could not draw? Therefore learn to draw. Go far enough in it to trust no unproved drawing-board for squareness; go so far that you do most or all of your work with T square, working along one edge of your board only; learn to do your minor work with two triangles and no T square at all; learn to sketch free-hand well enough to get the basis for a scale drawing of a dynamo or other machine or apparatus. If you draw well enough, you may even take a position as draughtsman, but only take it as a temporary affair; do not make it a permanency.

Very nice practice in drawing is given by making sketches of any apparatus you may be experimenting with. It will be of service as a method of clarifying the thoughts to draw it. A chemical or physical note-book kept on this principle, and embodying sketches of apparatus as actually used, may be made very attractive.

Making little free-hand drawings of apparatus involves, perhaps, more taste than artistic skill. Neatness is the first requisite,—and a sort of conventional style should be acquired. To give effect, shade lines may be used. You draw extra heavy the lines which indicate corners or edges of flat surfaces

which are so placed as to cast shadows. These in general are vertical lines on the right side of surfaces or objects, horizontal lines on the lower side of surfaces or objects, and diagonal lines intermediate between. A somewhat free or exaggerated use of these lines gives a certain effect to a poor sketch. But if you can draw correctly, you need not use them. They serve to conceal defects, and this is really one of their principal uses.

The question of whether you should practice free-hand drawing with pencil or pen comes up, some advising the use of a pen, because you must then draw rightly from the start, and facility of erasure or of rubbing out afforded by the use of the pencil is supposed to militate against correctness. If by pen-work the art of drawing correctly from the first line can be acquired, the pen should certainly be used.

For ink you may use common ink, but good effects are not so easily produced with it as with India ink. The liquid India ink and a lithographer's pen give a chance for very fine effects, but it takes a good draughtsman to fully profit by them. They are hardly to be recommended for practice, as they are luxuries, not at all requisite for the student.

In making sketches for dimensions to be quoted on, it is a good rule to use a rather large scale—the drawing should not be cramped. This gives plenty of room for writing in the dimensions, and allows one to note the smaller features, and even to make memoranda on the sketch.

Another great convenience in sketching is cross-ruled paper. Regular profile paper is expensive, but cross-ruled paper can be bought by the quire, and is almost as good as the other. If the lack of the heavy tenth lines is felt, you can rule off every tenth line yourself. But in most general drawing the absence of the heavy tenth lines will be a positive advantage.

If you care to take up descriptive geometry, which is an addition that well may be made to our recital of branches of study, you will learn it by drawing the problems with right-line pen, straight edge, triangle and dividers, which will not only teach you descriptive geometry, but give excellent practice in drawing. Every architect drawing a house, or mechanical draughtsman drawing a machine, follows the rules of descriptive geometry, whether he has studied it or not, often without knowing it even. It is quite possible that he may have never heard of it, but he uses it, and follows its laws in every line which he makes.

After descriptive geometry come shades and shadows. These are decidedly a refinement, and may be left as an accomplishment to be worked up if time permits. The same may be said of perspective. Yet one ought to know something of these as well. Both are simply extensions of, or rather a series of special problems in, descriptive geometry. They involve the determination of the intersections of planes and curved surfaces by planes and curved

surfaces, and of the *loci* of tangency to curved surfaces of planes and curved surfaces. They embrace very elegant problems, and if one has a fancy for graphics, they may be studied.

If the student wishes to practice drawing, he can just as well make problems in descriptive geometry, in perspective and in shades and shadows afford him models, as use pictures of Ionic capitals and of steam-engines for subjects. One trouble he may think is that a studying up of the problem will in each case be involved, but that will be rather an advantage. Several problems may be well learned before being drawn, in order to avoid breaking in upon one's work at the board.

While drawing is usually taught in the standing position, it will be found that in regular draughting-rooms high stools are apt to make their appearance. It is maintained by many, however, that standing is far healthier than sitting.

If possible, do not draw at night. Rise at five in the morning in summer and draw before breakfast; work late in the afternoon and put off your supper. It will not hurt you to eat by lamp-light. But do not spoil your eyes any more than necessary. You will in all human probability do them lots of harm by looking at strong lights, perhaps at arc lights, though you know it is a most reprehensible practice; so do not start in to abuse them by drawing at night. If you must do so, then have a good stu-

dent's lamp to work by, use a paper with dull or mat surface, and place the lamp so that the angle of reflection will not bring the reflected beam straight to your eye.

Blue-print paper is a very convenient adjunct to the drawing-room, and you may practice with it a little. Drawings on quite thick paper may be copied on blue-print paper if there is good sunlight. Printing on the reverse side of the copy, or another drawing or cut there, of course renders impossible the use of blue-print paper for copying a design from such paper.

Get a few points from a regular draughtsman as regards care of instruments, and the keeping of the points of dividers and the edges of right-line pens sharpened. Even the sharpening of pencils and best shape to give their points may be looked into. For sharpening the lead of pencils little pads of sand-paper are often used, but the writer's favorite is a file.

Conveniences in drawing are multiplying every year. Do not start to get all of them. You need but half a dozen instruments, and a large expenditure for a collection, whose principal value is in a heavy rosewood box strapped with brass or German silver, cannot be recommended. As has been aptly noted, experienced draughtsmen are very prone to keep their instruments in segar boxes. Perhaps they go too far in this direction.

In sketching wiring diagrams for houses, or for isolated plants, certain things have to be repeatedly drawn. Thus, if working upon such isolated plants, you will have to draw a great many times over conventional representations of a dynamo and steam-engine. In each case a number of lamps, all absolutely identical, have to be drawn, and there are various other features which have to be repeated often in such work.

For each of these it is well to adopt a fixed symbol or simple little drawing. Do not lose sight of effectiveness or neatness. A sheet of such drawings has been published, and gives an idea of how to carry out the above suggestion. Do not use any carelessly made symbol, or it may involve an error.

But if you have a great many such drawings to make, and this is possible, it would be well to have some rapid way of making them. Little stencils might be used, or if one is an adept at carving, representations might be cut out of wood resembling type, and from the types rubber stamps could be made.

It is well to get acquainted with engineers and find what conventional symbols or drawings they use for lamps of different kinds, for direct and alternating current dynamos and the like. Notice also how the crossing of wires without contact is indicated by a little loop or bend on one of the wires. After you have learned something about drawing, half an hour

or an hour with an electrical draughtsman will give you the clue to these special features.

In trade catalogues and electrical books will be found hints for drawing. Thus if you are making a large scale sketch of a dynamo or motor, you will get good models for binding-posts from such books. Other details are given in profusion in catalogues and are excellent for practice. Nothing adds more to the appearance and effectiveness of a rough sketch than accuracy of detail, or at least an evidence that the draughtsman knew what he was doing. Such evidence will be given by the binding-posts being of the latest type, by switches being of accepted model, and by a general up-to-date effect produced by attention to little things.

Under engineering in this book it is stated that attention to little things is of great importance for engineers. The same is to be said for everything in science, and in drawing it is as true as in any other branch. Such details of practice as those indicated will even compensate for other imperfections in drawing, imperfections due, perhaps, to absence of artistic talent.

CHAPTER VIII.

TEACHERS.

PRACTICABILITY OF OBTAINING ASSISTANCE IN STUDY —SOLVING DIFFICULTIES—MAKING EVERY ONE A TEACHER—UNIVERSITY EXTENSION—SCHOOL COURSES IN SCIENCE—DIFFERENT CLASSES OF STUDENTS—THE HARD WORKERS IN THE LABORATORY—DIFFICULTY OF TEACHING ELECTRICITY.

Is a teacher necessary for the branches of study required of the electrician? Can the limited amount suggested here be learned at home and alone?

While it certainly can, it is none the less true that a teacher will greatly facilitate matters. An hour every two or three days even, with a good teacher, will do much to settle the difficulties which will present themselves. A private teacher is rather an expensive luxury, and one which comparatively few can afford. But it must be that within the range of almost every one's acquaintance there is a friend who can be consulted. Perhaps it is a school principal; perhaps a man studying at or graduated from

college. In reading and studying a subject make notes of the difficult points as they occur to you. The next day try to solve them after a night's sleep. This will doubtless thin the list down. Then attack your friend with them. The fact that you are working under disadvantages will go far to excite a special interest in you and in your work. The thinning down process will cause you to present fewer difficulties for solution than otherwise would be the case, and the difficulties will be good ones. Some may be too much for your adviser. An aspect of earnestness will follow from all this, and greater willingness to help you will be insured.

At least it may be the result—but it may not. You may find yourself assuming the dreadful aspect of a bore. Then there is but one thing to be done, study alone. Do not mind how old you are. Alfieri, the Italian poet, learned Greek after he was fifty years of age. Note your difficulties, think over them day by day, and as you increase the list at one end, it will certainly be reduced day by day at the other. Some people hold that they can learn alone anything which they can learn with a teacher. There is no royal road to knowledge; there are, however, some long roads—very long ones,—and the teacherless road is apt to be one of the longest of all.

An arrangement might be made for one evening a week, just to smooth over the worst parts of your subjects. This would be better than nothing.

Make every one your teacher. The trolley-man and the electric-car conductor can doubtless give you some points in electricity. Try them, and see if their plain, every-day statements of the little they may know will not be of value. Make the acquaintance of the engineer at the electric light or power station, and acquire familiarity with volts and ampères, if it is only to the extent of letting your ears receive the words from another's mouth.

If there is a circulating library in your place of residence, the librarian may be able to help you, at least in the selection of books. But the work of librarians has so greatly developed in these days of library schools, that you will probably not find them possessed of much special knowledge of science as a rule. A good librarian has so much to do in keeping up with the requirements of the profession, that his or her knowledge of science is apt not to be specialized.

There is one splendid agent of instruction, the University Extension. After you have worked yourself into a perfect tangle of electrical study, and feel almost in despair (although you should not), attend a ten or twenty lecture University Extension course in electricity and see how your troubles will vanish. After each lecture the professor in these courses gives a conference to those members of his audience who desire it. Your first questions will show that you have been studying, and his interest in you will at once be excited. Without monopolizing him, follow

up the advantage, and try to keep him as a friend and adviser. At first do not present your hard points for solution. See if his lectures are not going to clear them away. Towards the end of the course you may present any that remain, and he will gladly help you out of your trouble.

The value of a course of University Extension lectures cannot be overestimated in such cases. They will supply the missing element, and do much to put the home-student on a level with the college man. All subjects may be treated in University Extension, and the subjects are determined by the directors of the course. Often a very little will turn the scale in favor of one or the other subject, so there may be no difficulty in getting an electrical course selected.

This little book will doubtless be read by some who are still at school. It may be possible for such to arrange with the principal to have a little extra science and mathematics. He will judge whether or not it is deserved, and whether it will be profitable or not. The tendency of advanced educators is to give more attention to science than formerly, and it is being made a feature in many schools. Where it is so, one thing is to be noticed—the way in which different pupils will take to it. Some like it as a novelty only, and after a few lessons work at it listlessly enough. Such present little evidence of fitness for professional life. Others are interested in it throughout—a good sign. To others it seems a little disappointing.

Chemistry in the laboratory loses, perhaps, the glamour it had before closer acquaintance with it. But these last we will suppose to have determination and to be determined to grapple with the subject despite its dryness. Pretty soon the dryness begins to disappear. If it is chemistry, they commence by keeping model note-books, with sketches of the apparatus, where anything special is employed. Reactions are all worked out and chemical equations written down. Perhaps the proportions of re-agents in the equations are calculated. For these chemistry takes a new meaning, and the third class, the slow, hard workers, give the best pledge of any for future success.

In a school with active principal and teachers one good student might often be able to bring about the introduction of a science course and of laboratory work. The teachers, if not advanced in practical science, would be, or should be, glad of the chance to work it up.

There is this also to be said: While a good teacher of any branch is rather hard to find, a good teacher of electricity is especially so. Where the very basis of a science is as uncertain as is that of electricity, where a whole superstructure is devoted to the phenomena of something so mysterious that it has not been and may never be defined—for there is every probability that mankind will never know what it is that drives the electric car, whispers a message across the ocean, carries articulations of speech from New

York to Chicago, splits trees and fuses quartz into fulgurites,—when the best attempts at a theory of electricity are based on the purely hypothetical ether, it must be hard to teach the subject. For a teacher must know far more than he teaches; he must understand within the limits of his teaching just where the weak spots in the theory are; he must know where a student will find special difficulty in understanding; he must not let a student go off thinking he understands where he does not.

A teacher must be the product of experience in general and experience in particular. This means that he must know the general principles of teaching, and must have special knowledge of the subject he is engaged on. Such a one is not easy to find. When such is met he is a treasure to the student, and from his very nature will appreciate an ambitious or hard-working learner.

The above summary goes to show that he who is his own teacher, when he could get another, is like the man who is his own lawyer. The latter, it is said, has a fool for a client. The application is obvious.

CHAPTER IX.

Electrical Factory Work for Students.

UTILITY OF FACTORY WORK FOR STUDENTS—WHO WOULD BE MOST BENEFITED—USELESSNESS OF SOME POSITIONS—SMALL AND LARGE WORKS—PREMIUMS PAID FOR POSITIONS IN FACTORIES—TIME EXPENDED IN FACTORY WORK BY STUDENTS—SCHEDULES OF COURSES.

The question of whether it pays to enter an electrical factory and work upon dynamos and the other products is one that can be answered in several ways. The answer will depend on who the person is, and under what auspices he enters the establishment.

If the man is quite ignorant of machinery and tools, then the sooner he enters some kind or any kind of a shop the better. For nothing is more forlorn than a purely theoretical engineer. He should above all things know the limitations of tools, how to use them, and how to direct others in their use. Thus in many cases the prize man from a college can do nothing more beneficial to himself than going into an electrical factory as a temporary apprentice.

It is to be presumed that many of the readers of this book will be skilled mechanics, many will be good amateur mechanics, and all others to whom it will be of any good will have a taste for the same art. The propriety of going to work will vary evidently for each of such classes, and for each individual of each class. Every one must judge for himself as far as general mechanics are concerned.

The non-educated, book-learned person, who does not understand anything about tools, evidently needs a machine-shop training worse than the one whom he may call uneducated, but who knows what his hands and arms are good for. It is useless to try to distinguish between the numerous degrees of proficiency in mechanics.

There is no question that some time may be beneficially given to an apprenticeship, as it may be termed, in an electrical factory. If it is possible, by any means, to go to one, and to work a little while in each of the different departments, or even in a few of the more important, then the experience would be of the utmost value, and of the most value to the man best prepared to profit by it. The skilled machinist would profit the quickest—the college student probably the most in the long run.

But as to whether it pays a young man to go in as a common workman in a large factory simply because it is an electrical one, and spend his day on one single thing, such as cutting washers, there can be little

doubt. He will learn no electrical engineering by doing this. It would be advisable for him to accept such a position only if there were a chance of advancement, but such there probably will not be.

In a small works there would be more chance. If everything is done in one or two rooms, then all is under one's eyes. A workman in such a place may be called upon to turn his hand to anything, and will have a chance to pick up much more than in the highly specialized system of the large factory.

One thing is certain. Without paying for the privilege, it will be very hard to obtain an entrance into the electrical factory. They are now besieged by young men, willing to make every kind of promise, if they will be only admitted to the desired precincts. Some of them, many of them, are of the highest promise, and would be of real value to any works employing them. But there is no room for the applicants, so it is very hard to get in. This may remove part of the difficulty, for it is possible that you will not be able to enter at all. It removes the difficulty of selecting what department to work in, for if you are admitted at all, there will be no choice for you; you must take any position assigned.

For those who are willing to pay a premium positions at nominal pay can be obtained at electrical factories. The Thompson-Houston factory at Lynn, Mass., and the Edison factory at Schenectady, New York, have offered to do this, and doubtless other works will be willing to follow their lead. The ex-

penditure of the premium is compensated for in part, in the case of the two works named, by the payment of nominal wages to the students whom they employ. Thus the premium is gradually recouped.

The time required in these courses is a serious thing. A whole year is supposed to be required for a college graduate, and more for one less advanced. The course once finished, the student has no claim upon the factory, and must hold himself prepared to find a position elsewhere.

The schedule of the courses supplied by these two works is given as examples of carefully selected outlines of student work. It will be seen that a quantity of ground is covered, and the demonstration is afforded of how much there is to learn inside of a great works.

The ideal education in electricity would seem to include such a course. The unsatisfactory part of it is that a year is spent in perfecting one's self in details of engineering which may eventually not be used, although they will always directly or indirectly be useful.

For one who is dependent on himself for his living the more ideal thing would be to start in some smaller works in any capacity, in the hope of working up. To such a one the long course of one or more years at the Thompson-Houston or Edison works is out of the question. If he can only obtain a position of any kind at bare living wages, and one which leads to promotion, he will thus get his best and most available apprenticeship.

Schedules of Students' Courses in Electrical Engineering at the Works of the General Electric Company.

LYNN, MASS., WORKS.

Kind of Work.	Weeks.
SHOP PLANT.	
1. Wiring	4
2. Shop motors	4
ARC DEPARTMENT.	
1. Arc lamp assembling	2
2. Arc lamp testing	4
3. Arc machine assembling and testing	5
INCANDESCENT DEPARTMENT, DIRECT.	
1. Incandescent machine assembling and testing,	4
2. Meters	2
3. Winding armatures	4
STATIONARY MOTORS AND GENERATORS.	
1. Assembling and testing	4
2. Railway and large generators	5
ALTERNATING SYSTEM.	
1. Machine assembling and testing	5
2. Construction transformers	1
3. Testing transformers	1
4. Testing mining drills and apparatus	2
Railway motor testing	3
Blacksmith shop	2
	52

SCHENECTADY, N. Y., WORKS.

KIND OF WORK.	WEEKS.
ERECTING DEPARTMENT.	
Assembling railway motors	2
Assembling small dynamos	1
Assembling large dynamos	1
Winding field magnets	3
Pillow block fitting, etc.	1
TUBE DEPARTMENT.	
Galvanometer work, testing instruments, etc.	2
WIRE DEPARTMENT.	
Conductivity measurements	2
Testing multipolar armatures	2
ARMATURE DEPARTMENT.	
Winding and connecting armatures, Gramme ring,	3
Winding and connecting armatures, drum	3
Testing armatures	2
MOTOR DEPARTMENT.	
Railway motors	3
Small stationary motors and generators	3
EDISON TESTING DEPARTMENT.	
Testing large motors and generators	4
Use of instruments and general testing	4
F. & A. DEPARTMENT.	
General machine work	2
Testing small motors, meter magnets, calibrating ammeters, etc.	4
Commutator work	2
Shop Wiring and power station	4
CABLE DEPARTMENT.	
Testing insulation, etc.	4
	52

Students are allowed to take only one of these courses, and are paid a very small salary, which increases during the year. At the end of the year no obligation to retain them is imposed on the company. A premium is also required, and only a limited number of students are received.

CHAPTER X.

College Education.

COLLEGES — DISADVANTAGES AND ADVANTAGES OF A COLLEGE COURSE — SCHOLARSHIPS — TUTORSHIPS — LARGE AND SMALL COLLEGES — APPARATUS—ELECTRICAL COURSE STUDIES.

It seems unnecessary to consider the question of whether a prospective electrician should go to college. If possible, he should do so, and after graduating should, if able to do so, remain at the college and take a post-graduate course. But this work is written principally for those who do not have the inestimable advantage of attending a college course. A college man generally knows far more on the day of his graduation than ever afterwards. For such as they advice is not needed, or rather is useless, because it would not be considered.

If a young man wishes to go to college, he will have to give up to it three or four years, perhaps, without making anything. Something may be earned by a bright man at college by coaching other students, acting as private tutor to prepare them for their examinations. As a man advances higher the

Electrical Laboratory, Stevens Institute.

prospects of obtaining such work increase, and it may become quite remunerative. Sometimes, too, there is a little literary work which can be done, not in connection with the college, but for some paper or publishing house.

All this is very desultory, and any success in earning money will depend on very hard work. And the same is apt to be the case also with the graduates, or at least with such of them as have no places open and ready to be stepped into.

The college course leads to several incidental advantages. A good man may obtain a scholarship, and be invited to continue his studies and to receive also a small but appreciable honorarium or salary while doing so.

A college course also opens up the avenue to teachers' work. A graduate who passes the course with honor may become connected as tutor with his own or with some other college. However low the position, it is at least the beginning of a career which may lead to a professorship. In some cases, where direct connection with the college cannot be brought about, private tuition, such as already spoken of, can be given at high rates by the known successful graduate.

What college to go to may be settled largely by the question of locality. In all parts of the country are colleges at which courses in mechanical and electrical engineering can be taken, and the largest and

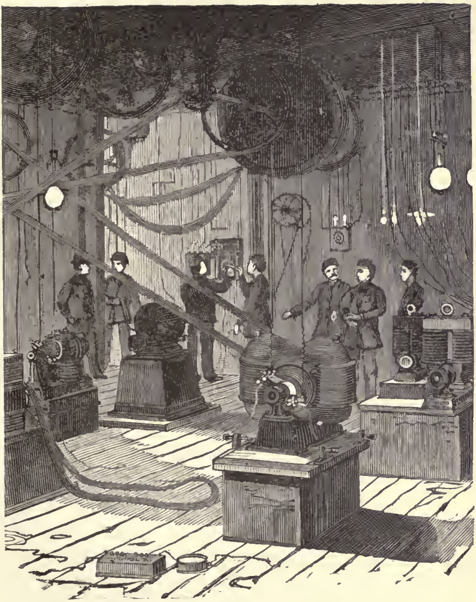
most richly endowed are by no means the only ones worth attending. The greater chance for personal attention on the part of professors in the small institution may overbalance the larger plant and more expensive apparatus of the other.

There is no end to accumulating apparatus,—a college may get infected by the same desire sometimes seen in adults for collecting apparatus of the most varied description. But better work is often done with the meager supplies of a small college or private laboratory than in the princely laboratory of a great university.

Very fine and expensive apparatus is needed for work in original investigation. This class of work is not supposed to be performed by students. So, as far as non-graduates are concerned, the elaborate apparatus is not needed at all; simpler appliances answering every purpose for them.

A part of the course in electricity, and a principal part of it, is comprised under mechanical engineering. Great tangent galvanometers and the like are but incidents of the course, for the work in mechanics is one of the most important things taught, and for it the luxury of apparatus is not needed. The practical portion of mechanics, namely machine-shop work, is, it is to be presumed, within the scope and talents of readers of this book to a greater degree than in the case of many or most college students.

All this leads to the conclusion that you need not mourn if you cannot take a college course, and espe-



TESTING ROOM, CORNELL UNIVERSITY.

cially need not be troubled if you have to go to some small college instead of to Cornell, Harvard or Columbia.

At Cornell University the course in electrical engineering for the first three years is identical with that in mechanical engineering. It is expressly stated that "none should apply for it unless strong in both mathematics, pure and applied, and in physics." It is fair to say that physics is really little more than applied mathematics. After three years' study in such branches as chemistry, physics, mathematics, work in the machine-shop and in the physical laboratory, a portion of the work of the concluding year is devoted to electrical engineering, tests of efficiency of dynamos and motors, photometry, and tests of telegraphic instruments, lines and cables. This does not suggest any great amount of work in electricity, pure and simple.

The mere summary of the electrical apparatus of Cornell University would fill a number of these pages, it is so extensive. Dynamos, motors, storage batteries, lamps, measuring instruments, authorized copies of standards, are there in great variety and profusion. A competent man could spend many months in interesting work under the facilities such a plant provides. Yet the under-graduate will find that his part among all these riches will be a comparatively small one, for his operations can be conducted with simpler appliances and without any reference to the prize pieces of the great collection.

If circumstances prevent you from entering one of the great universities, console yourself with the feeling that nothing is more mortifying than to spend four years at a university and on graduation to find no place open for you. The long struggle which the self-made electrical engineer may go through will begin earlier, and, it is to be hoped, will be sooner over. All of which is some comfort for the army of eager workers who, with insufficient means, insufficient facilities and insufficient education, are striving for the goal in competition with the sons of the rich, who are educated up to the highest pitch, provided they do not expend their talents on cribbing their way through college.

CHAPTER XI.

Steam Engineering.

WASTED POWERS OF NATURE—WASTEFULNESS OF COAL—POOR ECONOMY OF THE STEAM-ENGINE—COAL CONSUMPTION OF A STATION—UNFAIR RECORDS—ERRORS IN STATEMENTS—FADS—ENGINES OF DIFFERENT TYPES—REVOLUTIONS IN ENGINEERING—STEAM ENGINEERING A SPECIAL STUDY.

Steam engineering is the epitome of the station engineer's acquirements. If he is only a first-class steam engineer, and there are comparatively few of them, he is nine-tenths qualified to conduct a station. There is nowhere to be found, except on steamships or in cable traction plants, an instance where steam and heat play a more important part than in an electric power or light generating plant.

For, unfortunately, we still have to see the force of gravity actuating millions of horse-power of potential energy upon this earth every twenty-four hours without our utilizing any of it directly,—we know that the thermic conditions of the natural world bring about kinetic energy which, utilized, could sweep

the steam-engine out of existence, when we realize that the succession of night and day or of summer and winter are sources of energy before which the coal-mines of the earth fade into insignificance,—we know that it is conceivable that the difference in velocity of the earth's equatorial and polar regions may be utilized by succeeding generations to do their work. But we have to be content with knowing that our forefathers proportionately used the tides and the winds to a much greater extent than we do, and, bowing to our destiny, we dig up coal and place it on the surface of the earth at after all a very cheap rate, pulverize and screen out of it, and so waste, a great proportion, and then by rail and vessel send what is left hundreds and thousands of miles at great expense, to be burned up under a boiler, and to have utilized, perhaps, one per cent., or, by a great triumph of engineering, as much as ten per cent. of its energy Then when the energy which its carbon represents in being uncombined with oxygen is gone, and it is burned, we find plant life undoing our wasteful work and gradually separating the carbon and oxygen again. But this separation is so slow that, as far as economics are concerned, it might almost as well not take place at all. For our healths this separation may be very important—it is hard to say how much or how little.

The steam-engine is a dreadfully crude affair. Every electrician gloats over his dynamos and motors with

returns of ninety per cent. and upwards. He is troubled by no second law of thermo-dynamics, except for thermopiles, which are accordingly rejected in practice. All is clear sailing for him, except that, having built a dynamo of ninety-eight per cent. efficiency, he has at one fell swoop to lose ninety per cent. of its efficiency, because he has to turn the armature, and a steam-engine is the most generally available means for doing this. The steam-engine undoes his economies.

Everything in a station hinges on consumption of coal. It is a question, as already intimated, of how many pounds of coal per hour must be burned to keep a little filament of carbon at a white heat. Sixty inches of such filament gives a rough gauge of a horse-power. It will make a great difference in dividends if one and a half pounds do it, or if ten pounds have to be burned each hour to keep up the supply of energy for these few inches of ignited carbon filament.

Considering then the station as a contrivance for converting chemical potential energy into electric kinetic energy, its successful running consists merely in developing the highest possible efficiency in the conversion. Unfortunately the conversion involves a number of steps, each one with its own loss, so that a very small amount indeed of the total chemical energy is utilized. It does seem a pity that after coal has been mined and transported hundreds of miles

we only get, as just said, a few per cent. of its potential good out of it. So, if you have to run a station, concentrate your ideas on real economy. Figure out every day the efficiency in practical engineering units of each of the appliances from boiler to dynamo, and thus keep a watch over the whole. A waste located is half-cured.

Real economy is the goal, not book-keeping economy. By proper or rather improper systems of records the books can be made to show much higher figures than are actually obtained. Thus suppose a superintendent is proud of his boilers. He weighs the coal, weighs the ashes, and measures the water. The weight of the ashes is subtracted from the coal. But as the ashes are raked out wet from the ash-pans and are weighed wet, the coal is favored to the extent of the water. The latter of course figures as ashes, and is subtracted along with the weight of the true ashes from the coal to get the carbon.

This is a small matter, but it is an error ; it favors the boilers, and, in conjunction with the system of wet ash-pans, it accumulates error. All the water evaporated in the ash-pans is uselessly evaporated; all removed with the ashes is wasted,—and on the books all this may be credited to the work of the boiler.

A chemical determination is executed sometimes within a few hundredths of one per cent. One-tenth of a per cent. is good work. One-tenth of a per cent. of a ton of coal is 2¼ lbs. about. Far more than

that amount may be weighed with the ashes of a ton of coal. A station constructed for accurate working should not be subject to such errors as this, and the carbon burned should be known within a fraction of a per cent.

The above is only given as an example of how an error may creep in. An obvious way to correct it would be to make an allowance for the water absorbed by the ashes. This could be determined accurately on a sample every now and then, and the tare thus obtained could be employed for a month at a time. The error is also an example of a temptation, for it increases the recorded efficiency of the boilers. It is an example of "doctoring" the record. If a chemist works to within a fraction of a per cent., using only a gram of substance, an equal accuracy at least should be obtained where hundreds of tons are operated on.

There are fads in everything, and if a superintendent's fad applies to the engines, the above "doctoring" will probably not please him. It will be against the engines. This suggests another reason why the utmost accuracy should be adhered to. An unfair figure in favor of one step tells against the other steps, and is robbing Peter to pay Paul.

Do not, therefore, yield to fads. Faith need not be placed in a single kind of boiler, when there are possibly others as good or better. Do not acquire the idea that only one kind of high-speed engine will run

a dynamo rightly, when in a neighboring city some other plant may be doing better work with a low-speed engine than you can do with a high-speed one.

One very common infirmity of engineers is connected with compound, triple and quadruple expansion engines. They are apt to imagine that the *ne plus ultra* of economy inheres in some one of these types of engines. Yet it is hardly going too far to say that nine out of ten engineers would be unable to say why a compound engine is more economical than a single one.

It is therefore dangerous to allow one's self to be carried away by overenthusiasm. Revolutionary devices in engineering are not frequent. One is fortunate and probably long-lived who sees the advent and success of a single great improvement which is itself destined to endure. The present generation has seen revolutions brought about by electricity, but the reference is to engineering in general—not to the *fin de siècle* miracle which electricity has shown itself. A revolution is to be looked for any time from its more extended applications.

You must make steam engineering a very special study. Carnot's cycle, the Carnot diagram, the laws of thermo-dynamics, the laws affecting the economical expansion of steam in an engine cylinder must be familiar. From these more basic subjects the descent must be made to subjects of minor significance yet of no less importance. These affect the motion

of steam in pipes, the loss in its energy due to cooling in such pipes, the evils of throttling, the proper use of lubricants, even the proper packing of a steam-engine is a subject to be studied. Sometimes with hammer and a calking-iron, perhaps with an old cold chisel, or, if mercifully disposed, with a stick of wood an engineer will jam packing into a stuffing-box on a cylinder head, and will then with spanner set up the gland in the effort to get the place steam-tight. Before he stops he is sure to get it very tight indeed, in one sense—tight for the piston-rod, which has to fly in and out many times a minute. Power is wasted in such practices. Energy is required to overcome the friction incident to such packing. After a while the piston-rod perhaps begins to score, and then the packing is harder to manage than ever.

So all through the list there are endless details to be understood. Many will be acquired by observation. Never go through an engineering establishment without learning something new. It may only be the way of lining up an engine, or some trick in connection with the journal boxes, or crank-pin lubrication,—whatever it is, it is worth learning, if only for comparison. A good observer has great advantages in acquiring information in this way.

CHAPTER XII.

The Manufacturing Engineer.

DIFFERENT WORK DONE IN FACTORIES—DYNAMO AND MOTOR BUILDING—IMPROVEMENTS IN DESIGN—FAULTS OF CHEAP MOTORS—IMPROVING THE MAGNETIC CIRCUIT—SMALL FACTORIES—BAD INSTALLATION OF GOOD MACHINERY—MAKING PARTS FOR DISTRIBUTION OF ELECTRIC POWER—METERS AND THEIR DEFECTS—TESTING MATERIALS.

The construction of machinery is one branch of electrical engineering. From the great factory where generators of hundreds of kilowatts capacity are turned out day after day to the one or two room work-shops where a few men find occupation in manufacturing condensers or some similar appliance—from the telegraph instrument makers' where little bits of brass and steel are worked up by the thousands into keys, sounders and switches to the model maker who busies himself with special apparatus only—from one extreme to the other a very wide and diversified field is passed over.

Thus when we speak of an electrician manufacturing electrical machinery we may refer to the superintendent of a factory, to the foreman of a room or department in a factory, or to some one who, depending on himself alone, is slowly building up a business on an independent basis. The separate branches of this part of the profession are as different as separate manufacturing industries. In one case castings of one to twenty tons will be in question, where large dynamos have to be made. In the other case the brass parts of telegraph sounders, and the cores of sounders and of relay magnets may be among the largest pieces produced. The manufacturer of condensers handles tinfoil, paper, mica and paraffine; the maker of storage batteries uses lead, lead-oxides and glass or rubber cells. It would seem as though any one could find something adapted to his scope in such a variety.

Perhaps the manufacture of dynamos and motors is the branch that appeals most strongly to the younger electricians. There is something attractive in the idea of supplying the great engines of electricity, of being in the fullest sense an electrical engineer, in dealing with the machines which have created the electricity of the present day. They are the subjects of calculations which have great interest, as involving the application of lines of force, reluctance of materials and distribution of core and pole pieces. The symmetry of the field depending on the shape of the

pole-pieces and affecting the action of the armature, the work of the latter is changed by adding to or taking from the different parts of the poles. There is something fascinating in the idea of changing the action of an armature by simply varying the shape of the apparently inert and actually motionless castings or forgings which conduct or regulate the distribution of the lines of force.

Magnetic leakage and its prevention appeal also to the mind of the electrical constructor. The ideal dynamo field, where the aerial lines of force all go straight across the air-gaps, and where one-half of the energy given to the field is not uselessly expended in maintaining lines of force arching about in curves as pretty as useless,—this ideal is a sort of flying Dutchman which never can be caught, but which still tempts pursuit, though we know it to be hopeless. But when the cheaper type of motors with long slim field cores and attenuated pole-pieces made of the poorest quality of chilled castings are inspected, there seems plenty of room for improvement in design. For it is as easy to design a small dynamo correctly as it is to design a large one ; and if one is making even toy motors for boys, it seems a pity to design them so badly that half the energy goes to the field, and that most of what gets there is absolutely wasted. Thin cores of iron of low permeability have much to do with the sins of dynamos and motors.

Sylvanus P. Thompson is emphatic in his affirmation

of the merits of what he calls a stumpy electro-magnet. His very interesting account of the different shapes which investigators have given magnets is worthy of recommendation to the young engineer. Many of the attempts which have been made to do away with the air-gap and copper-gap reluctance do not seem to have been based on the right premises. It certainly seems as if occupation for investigators could be found in improving the magnetic circuit of dynamos and motors. The return of energy is now very satisfactory, and as reduction of leakage does not imply a very great increase in efficiency, there is not room for much of improvement in this direction. But what a reduction of leakage does imply is a reduction in size, a saving in weight and in cost of metal, an increase in convenience, such as freedom from liability to magnetize watches, and a more accurate working as a larger percentage of the field would be utilized, so that regulation would be regulation of a larger proportion of efficient lines of force and of a less proportion of waste lines.

All this is a suggestion of work which might be studied in the factory.

Again a small business can perhaps be built up on dynamos and motors, which business may be trusted in time to grow to large proportions. There is no need of starting a foundry—the castings can be made at a few cents a pound by the regular founder. A pattern shop is not even necessary ; the work can

be drawn and sent to the pattern maker. The winding of the cores and armatures can be done very well in a small shop, the shape of cores and distribution of material can be well worked out at the drawing-board, and personal work upon the machines will give great scope for ingenuity in providing for details of construction. Little capital is needed, and if customers can be found a living can be made. This, however, is a very important "if." It is a word which has a way of taking the beauty out of many a project.

In this line of manufacture you have to compete with cheap motors of perhaps five per cent. efficiency and with high-class motors and dynamos of ninety-five per cent. efficiency. It is easy to improve on the first: there is little chance of improving on the latter. It follows that if any young man believes that he is going to make a field magnet core which will revolutionize dynamo building, he is in all probability going to be disappointed; a thing very good for the moral system, but rather a bitter tonic in some cases.

One aggravation about the business is that the best efforts at the production of high-grade machinery may be nullified by the use made of the product. Poor connections, improper use of rheostats, wrong speed of running and other mistakes and mishaps may cause the best dynamo to give a very poor record. The business of making large dynamos has, however, reached very high perfection. The days

of multiple cores, involving wasted copper and uselessly absorbed energy, have gone by. Permeance and reluctance mean as much to the dynamo builder as do conductance and resistance to the working electrician. Ideas have become greatly clarified in the last few years.

It is easy to see that the dynamo builder is in possession of one of the most interesting fields of work. It is one which seems to afford a chance for the beginner in business. It is one which gives temptation for experimentation, temptation which may often lead to fruitless work, the reason of which is that the best electricians of the world have been giving attention to dynamo design.

An electrician may do other things than experiment in dynamo design and calculations. There is much to be done in the conveyance of heavy currents, in providing insulation for heavy conductors, and in solving the problems of constructions for outdoor work, such as the prevention of leakage on a long trolley circuit; these and similar things are problems which verge upon another branch of the profession, but the factory has to supply the parts for carrying out the requirements. New problems are constantly coming up, and quantities of old ones are unsolved. A small low-speed motor of any reasonable efficiency, gearing that will stand the wear of reducing 2000 revolutions per minute to a hundred or less, —such are examples of the old-time problems on which work may still be done.

The subject of electric meters is an attractive one. Much as people have complained of the gas-meter, they have more reason to complain of the ampère-meters supplied for metering electric energy. These are based on a constant voltage. But the fall of a single volt of potential brings about a directly measurable decrease in energy, of which the meter takes only indirect account. The fall, however, involves much more than the percentage of watts due to the difference between 110 and 109 volts, for it makes all the lamps burn at less than their proper candle-power. The customer is buying light, and he suffers an injustice if he is required to pay for energy that gives an imperfect rendering of light. He cares nothing for obscure energy. Yet, as far as his meter is concerned, it would go on metering energy to the debtor side of his account if the voltage fell to 100 and lamps were turned on in vain hopes of getting some light, they remaining black while using energy.

The system of metering electric energy seems open to improvement. The best minds in the profession have not succeeded in evolving a perfect meter. In a constant potential system the factory itself, in maintaining the voltage, is a portion of the meter. Like improvements in all branches of electricity, it is hard to improve the existing appliances for measuring the article supplied. But a true energy meter, or a meter that would automatically cease recording as the voltage fell below a certain minimum, would seem a desirable thing.

There is another good feature connected with a factory. It is the possibility of expansion and of development of new lines of work. A small works building a few dynamos may expand and supply lamps and full lighting plants. It may branch out into telegraphic instruments or storage batteries.

An electric light and power station in the normal state of things grows, but its growth is mere expansion without the branching out into new lines. A very large and a very small plant are the same thing except in size. The same qualities and capacity of engineer are required in both large and small stations, but the electric factory brings in everything. The glass-blower's art and the chemist's profession join with the machinist's trade in its productions. A bright, well-educated electrician will find a manufacturing establishment where electric goods are made a most congenial field of work.

Materials have to be tested. A knowledge of the resistance of insulators, their dielectric capacity, the qualities of copper as a conductor, and of iron as the material of a magnet-core, or transformer-core, is of the utmost importance to the constructor. Every sample differs from others of the same material. The figures of the books for constants of copper, German silver, iron and other materials are but approximations. The rightly ordered factory will be constantly in need of new determinations. The testing electrician may find opportunities for good work without

ever leaving the laboratory. He may have much to do in determining what material should be used in dynamos, and in so doing he determines their good or bad qualities.

Laboratory work plays so important a rôle in many factories that the necessity which exists for an engineer to be familiar with electrical tests of all kinds is obvious.

This may read as if factory work was the best field. But there is no best. Simply pointing out the features of each branch of the profession and venturing to show that there are lines of investigation and improvement well worth following up, pointing out these things in order to inculcate the wisdom of being on the lookout for chances to improve, this does not imply that the electrical manufacturer is higher in the profession than the outside engineer who erects factories and railroads and puts up plants of all descriptions. All kinds of work are attractive and interesting, and we can but hope to present the best side of each kind of electrical work, with some glimpses of the worst side.

CHAPTER XIII.

The Constructing Engineer.

THE ERECTION OF PLANTS—GENERAL KNOWLEDGE REQUIRED—THE GENERATING PLANT AND ITS FUNCTIONS—BOILERS AND ENGINES—ADVANCED SYSTEM OF RUNNING PLANTS—PRACTICE AND THEORY.

One branch of the engineer's art consists in the erection of electric plants. Such may be power or light plants, including the central station where the electric energy is generated, and the distributing system in use outdoors and in the houses of customers. Trolley work, underground conduit and cable work also come under this head.

The thorough engineer should be able to design and lay out all of the plant which he is concerned with. This includes the buildings and roofs as well as the counter-shafting and machinery. The old-fashioned engineer in other departments did all such work in the days when electricity was unknown. But now the great contracting establishments take this off one's hands, and bids can be asked for the whole establishment, from foundation to roof-truss,

from steam-gauge to dynamo. A man who lazily sits at a desk and dictates letters asking for bids, who opens the same and selects the lowest, and then abandons the site to the operations of contractors, will call himself an engineer, although ignorant of the relative degrees of difficulty involved in the construction of a one-faced or two-faced brick wall, and perhaps unable to appreciate the true intricacies of an eight-inch wall pointed on both sides.

If you call yourself an engineer, be one. If you are to attend to the erection of generating stations, try to know something of stone-work, of brick-laying and of carpentry. Remember that a contractor does nothing for fun and little for glory. Duty to your employers exacts close watch of their operations on your part.

But one may claim to be an electrical engineer only and not a civil engineer. But civil or uncivil, an electrical engineer, without any assumption of universal knowledge, may have common-sense enough to know how buildings are constructed, to know that a wall should be plumb, to know that thin mortar joints look better and are better than thick ones. If Portland cement is prescribed, he can readily rig up a simple machine for testing the strength of briquettes. If he has followed the suggestions contained in this work, his education will have carried him far enough to enable him to do this much and more without any very prolonged study.

But do not let him fall into the error of supposing himself to be a universal genius. A man cannot have a profound knowledge of everything in this profession. So an engineer is perfectly justified in calling in expert assistance in superintending important work. Special inspectors may justly be required by him for the protection of his company.

When the plans for the building are in question, including the location of engines and dynamos, the arrangement of counter-shafts and situation of the boilers, it would be well to examine other electric stations, so as to get hints as to disposition of parts from them. An electric power station is but a giant coal-consuming agency, the potential chemical energy of the coal and oxygen of the air being converted into the kinetic energy of heat and that into the mechanical energy of the engines. This in its turn develops the electric energy to be sent over the mains and wires of the distributing system.

The plant is to be considered a unit. It is one thing—an entity devoted to one single purpose, the absorption of the potential energy of separate carbon and oxygen and the production of kinetic electric energy. This operation has to go on day and night under accurate superintendence. The superintendence in question is to go to secure the saving of every pound of coal and of every day's labor possible, which exacts a distribution of parts conducive to such ends. The works must be systematically

arranged so that everything can be done as cheaply as possible, and so that complete oversight of all operations shall be easy.

For the sake of economy the most advanced type of boilers and engines must be chosen. The second law of thermo-dynamics is not being precisely beaten, but is being robbed of part of its terrors by the use of very high-pressure steam worked to great expansion. Exhaust steam might theoretically be far below the temperature of boiling water. The great trans-Atlantic steamships are models in this respect. If a table of data of ocean greyhounds for the last ten years is inspected, the rapid rise in steam pressures employed will appear remarkable. To accommodate the expansion several successive cylinders are employed. This prevents too great condensation of water in any one cylinder. In the electric light station great thought and care should be devoted to getting good engines. A ship at sea in a gale, tumbling and rolling about as if ready to go to pieces, should not be able to give a modern electric generating station any points on economy of steam generation. Yet it is to be feared that it sometimes can.

The engines must be a subject of consideration. A fad for high-speed engines, a fancy for an engine of fewest parts, an idea that it is a great thing to cast cylinder-head and bed-plate in one piece, should not be the controlling motives in buying them. There are important generalities that apply to all

engines, and these the engineer should take cognizance of. A cylinder exposed, unlagged, to the air, steam-pipes which wire-draw the steam, and cause a good part of its energy to be expended before it reaches the throttle-valve, a tightly packed stuffing-box through which the steam has to force the reluctant piston-rod, a setting of the valves which cushions the piston inordinately,—these and many other defects have to be guarded against.

The erecting engineer may have at his service the best dynamos and boilers, and all may be spoiled by a bad engine. If the latter is also of the best quality, bad piping and other defective features may spoil its efficiency.

In the steam generating part of the plant, the boiler-room, there is room for engineering. A hot fire-box and a cold chimney are the first signs of efficiency there. This efficiency the boilers may give, and yet it all may be lost. Want of adequate protection of the boiler from loss of heat may destroy entirely the furnace economy. Good setting of the boilers and proper protection against loss of heat by radiation are of the greatest importance.

The advanced system of running plants is to weigh the coal, weigh the ashes, and weigh or measure the water. The arrangement of the boiler plant must favor the easy carrying out of these operations. If anything has to be hoisted, ashes will be cheaper to hoist than coal. Throughout there is room for com-

mon-sense. The books may disclose the accepted sizes of pipes; your plan will be an improvement on this if you will use pipes of twice the sectional area. But if you do not protect your pipes by non-conducting covers, the large pipes, on account of their larger cooling service, may be worse than the small ones.

In all the arrangement of details and planning of the works a good strong judgment will do wonders. The effect of all your good work will be possibly quite perceptible, but here, as in all engineering, it is very hard to make much of an advance on the work of your predecessors. A great deal of thought and of expense may be involved in some of your new ideas, and so meager a result obtained, as not to justify you in carrying them out. It is wonderful how well an idea may appear on paper and how poorly it may work out in practice.

CHAPTER XIV.

The Station Engineer.

THE QUALITIES REQUIRED—DEALING WITH MANKIND—THE PUBLIC—COMPLAINTS—IMPORTANCE OF COURTESY — SKILLED WORKMEN — PROMOTION FROM THE RANKS—STATION ECONOMY — THE PRESIDENT—EXECUTIVE ABILITY — DEPENDENCE ON THE FACTORY.

An engineer may have the good fortune to be engaged in the erection of a plant which he is to run. Then he can arrange every detail to suit his own ideas with the certainty that he is working for an appreciative audience. But often the engineer who is to conduct and superintend the operations of a plant has to possess a different range of qualities than those possessed by a constructor. Often, as has been said, an engineer will be the nominal erector of a plant, while it will have been really due to the contractors, and after they are through he will receive the plant and proceed to get it into regular operation. Some of the qualities which the station engineer requires are touched on elsewhere.

He is a manager of men; he not only has to manage workmen of the laboring and of the technical

classes, but he also has a more or less direct intercourse with the public. The public, as the customers of the company, are served by him, and their complaints sooner or later reach him. If an electric light and power station is in his charge and the voltage falls a little, he is robbing the customers of an immense total of light, and will be apt to hear from them very soon. A variation of speed in the engines will be reflected over the entire area of the district in a fluctuation of the lights.

The public may never know the engineer, but they will know where the office of the company is, and thither they will wend their way with complaints or will write in case of trouble. These complaints will be passed on to the engineer, so that he will be in constant touch with his public, as long as things go wrong. His study of human nature will find a good field for exercise and practical application if the works are not well run.

As long as the operations at the works go smoothly the public will be little heard from. They have now been educated in electricity. They do not amuse themselves by searching for weak spots on conductors or on arc-lamp frames whence to take shocks. If a carbon filament gives way, the accident is taken philosophically. They have by some mysterious process learned to accept the bills rendered for electric service as correct, something they never would do in the case of gas bills. So, if you ever reach the point

of having a station put in your charge, you will find a pretty well-trained set of customers to be served. By keeping your engines and belts in good shape, and by selecting good men to regulate the output as to the potential or current, you should have no trouble in pleasing the public.

But if things go wrong, the complaints must be met. Here courtesy will apply. A polite treatment of a complaint is appreciated by the complainer, and is accepted as an apology. "A soft answer turneth away wrath." If the engineer never meets the customers, he may have to dictate measures to the secretary or other representative of the company who does meet them. Let him put himself in the place of the official, and in the light of his own technical knowledge see how he would answer the complainers. Then he can impart the general statement to the official in question.

Laboring men have to be dealt with, which is not a very difficult matter. But there will also be a more troublesome task in handling technical workmen, men who have a slight knowledge of electric work, and who are perhaps unduly impressed with their own superiority due to such knowledge. Such men are most useful. They have a detailed knowledge of certain things, which is valuable, and would be well worth possessing. But its range is very limited. It therefore is necessary to keep them within their prerogatives, and because a man knows just how to

humor a refractory lamp, he must not be accepted as counselor in the operations of a station.

A young man may work up to the position of station superintendent by promotion from the ranks. He may begin at the very lowest position. If he does so and gradually works up, he will obtain this detailed knowledge of which we have spoken. Such a graduate of practical life, if he possesses the other qualities and education enough, will make the best kind of a manager. The men will soon find that he has the same precise knowledge upon which they pride themselves, however slight in extent it is in their own individual cases. Any trouble is quickly met and remedied. An electric company of the sort described should encourage students. As the navy or army has its cadets, the electric industry should have the same. Perhaps the simile or designation of cadets applies better to college students. But in the army or navy some of the best officers have worked up from the ranks, and the same is true of the electric industry. The younger men should be encouraged, for in them is the making of the best grade of engineers and managers.

Mechanical and steam engineering will constitute a great part of the work of the superintendent of a plant. While everything is subordinate to electric energy and its generation and distribution, a few simple rules will cover the ground of most of the electrical problems. But the engines must run with

exact regularity; the boilers must be managed with the utmost skill, and economy must be obtained in all. The exact registry of coal, water and ashes gives the criterion of the work that is doing. The electric energy delivered, reckoned in watts, gives the other figure for reckoning station economy, while the units paid for by the customers tell how efficient is the distribution—the average drop is the criterion of this efficiency. Then from the pounds of coal burned in proportion to the watts paid for is deduced the total efficiency of the generating and distributing plant reckoned as a unit.

A business man will soon grasp the above generalities. A little figuring will enable him to see how much coal is burned to extract one dollar from a customer. He will easily get similar labor figures. A good president or executive officer will hold an engineer down to a very exact account of expenditures and results.

In the successful conduct of a generating station and distributing plant a full knowledge of electrical engineering combined with that indefinable quality termed executive ability is required. The calculations to be made are few and simple ; they are all done in the factory. The dynamos in their windings and shapes of core embody some of them. The measuring instruments are all standardized. All ought to run smoothly. But sometimes things go wrong, and "bugs," as the telegraphers named them,

have to be located and got rid of. To do this it is evident that a thorough knowledge of the subject is required, together with a certain amount of instinct or intuitiveness.

The preparation needed for this position is best obtained by the means already suggested, by graduating from the ranks of station employés. But in the general education it is rarely worth while to make any special reference to it in one's studies. If you do and expect to stumble by good luck and your merits into such a position, you will be apt to find that, while the unexpected does not always come to pass, the expected has a great way of not happening.

In station management the superintendent is captain of his ship, and within his own limits is supreme. This is always a pleasant feature. Yet the position is far from being a high one. A plant gets to running like a clock, with now and then an annoying break-down or accident, and there is no pretense that very high abilities are required in superintending its operations.

If new electric machinery is wanted, the factory supplies it. There is not the least occasion for the station superintendent to have more to say about a new dynamo than to specify its capacity or constants. He will have nothing to do with its design or structural peculiarities. He receives everything in the way of supplies in the ready-made condition, and his hand can hardly leave the mark of his individuality

upon a collection of machinery with whose origination he had nothing to do. There is often a feeling of subordination to the factory, which feeling sometimes assumes an unpleasant aspect, when it seems as if the factory supplied the brains.

But it should be remembered that any commercial dynamo is the outcome of numerous trials and is rather a growth than an invention, and the feeling spoken of seems unjust. The years of modern electrical science are the creators of the dynamo; the factory supplying dynamos is availing itself of these years of work and study, and it is quite possible that in the factory no one has in the full sense designed the dynamos made.

The species of jealousy described is out of place and to be deprecated. The station engineer, by the selective processes of modern life, is rapidly being differentiated from the constructing engineer. But both of them are guided by the experiences of others. Their apprenticeship is largely in the lives of their predecessors.

CHAPTER XV.

Inventing.

SHOULD ONE BECOME AN INVENTOR ?—WHAT CONSTITUTES A SUCCESSFUL INVENTION—CONSTRUCTION AND INVENTION—USEFUL AND USELESS INVENTIONS—THE PRACTICAL VIEW TO BE TAKEN—NOVELTY AS WELL AS ORIGINALITY REQUISITE—PATENT SUITS—PATENTS AND CAVEATS—CLAIMS—ESTABLISHING DATE OF INVENTION

What can one conversant with patents and patent law say about inventions? Should an engineer or practicing electrician invent and patent his inventions? It is hard to remove all prejudice and answer the question dispassionately.

The qualified inventor, one who distinguishes between the ingenuity of construction and the genius of invention, one who has studied up his case so effectually that he knows whether there is a probable market for his patent or for things made under it, one, finally, who does not overestimate the worth of his own achievement, such an inventor is a rarity. For too often the inventor is one-sided and dreadfully sanguine, and imbued with a sense of his own

ingeniousness. Men of one idea are grand or small according to the size and dimensions of the one idea, and according to their own qualifications for carrying out their chosen end.

There is ample room for invention. A good invention is a greater service to humanity than it is apt to be to its originator. Therefore, if capable of it, invent all you can and patent your inventions.

But are you capable of properly inventing? There is the difficult question. To decide, ask yourself the following queries,—if you can answer them satisfactorily, you may call yourself qualified to invent.

A difficult piece of machinery may come to a shop to be designed, merely a general idea of what is wanted being given by a rough sketch, with explanatory remarks radiating from it in all directions. It is taken to the drawing-room, and the draughtsmen open fire upon it. The slight sketch and directions are amplified, gearing is calculated and introduced, and gradually a perfect machine, embodying probably points of construction not contemplated in the original sketch, is produced. Yet in all this development there may be no invention. The original smeared and labelled sketch may embody a most ingenious invention, while the elaborate scale drawings have grafted upon it nothing but features of construction. The invention appears in each and shines out through it, but it is just as clear or clearer in the original sketch. The first question alluded to above

is shadowed forth in the supposed case—Can you distinguish between construction and invention?

The next question refers to what you will do with your invention. Do the public want it, or have they already something better? This must be answered dispassionately, and you must not be led astray by hope. The commercial market must be judged and estimated. Such operation is rather within the functions of a business man than of an inventor. It would be well if inventors had both before and after their inventive periods the services of acute business men. Before expending time and thought upon an invention their associate would tell them what was the prospect for a market. After completing an invention the same ally would know what to do with it. But the question must be asked and answered properly by yourself if you are capable of inventing.

Assuming that the two questions can be answered affirmatively in your case, invent all you wish to. A due attention to the requisites indicated will have a very restricting effect upon your work. The striving will be after the hidden genius of invention,—mere ingenuity of construction will be looked down upon as not to the point. The most complex designs will be considered subsidiary to the central idea, which is the invention. The whole will be subsidiary to the public need for it.

Mere beauty of conception will be put aside and the practical view taken of anything tempting to in-

vention. The utility of a proposed thing will be duly considered and weighed before time and thought are expended on inventing it. There is no glory in inventing,—it should not be regarded as a scientific achievement, but only as a practical one. Invention stands upon another plane than do investigation and discovery. The latter may be entered on from pure love of knowledge and without any consideration of the practical aspect of the case. The ideal of a pure scientist is to make original and theoretically important discoveries,—the ideal of an inventor is to make original, novel and practically valuable inventions.

Thus the inventor seems to stand upon a less lofty plane than does the pure scientist, and perhaps he does so. The one strives for money, the other for glory. The majority of the readers of this work have probably a due regard for the emoluments of the profession. The money derived from laboring in it is earned legitimately, and is a right end to have in view. Therefore, if you can do so, invent.

If you do invent, be prepared for disappointment. The Patent Office may be the first to nip your aspirations in the bud by showing an anticipation of your invention. What you have invented may be original but not novel. "Great minds leap," and some one may have trodden your path before you.

If the ordeal of the Patent Office is passed, the making a business success out of your patent is a

difficult task, and one for which you may be altogether unfitted. An active business man is wanted, who will see enough in your invention to justify him for the time being in taking up the rôle of a man of one idea and of pushing your invention on to success.

The next ordeal may be that of patent suits. These you may have to bring, or you may have to defend yourself against others suing you for infringement. Money is required, and the patent has to undergo adjudication by the Court, perhaps to be declared invalid and worthless.

It is an anomaly of our patent laws that the scope of an invention is limited by its claims. A bad attorney, in drawing up a patent, may give it insufficient claims. For this there is no help. The courts, in the re-issue decisions, have virtually estopped the one avenue of relief that was open for inventors in this regard. Everything depends on the claims.

Hence a competent attorney should be employed to take out the patent. He should be one having experience in law suits. His talent should lie in an ability to draw up claims which will stand examination in the courts,—he should not simply try to get your invention in any shape through the Patent Office.

Do not take out a caveat. This is about as useless a thing as our government provides. For the ten dollars you pay for it you get nothing except an agreement that the Patent Office authorities are to

inform you if any one applies for a patent for the same thing. If they fail to give such information, you can do nothing, and your caveat is useless. If they do so inform you, you apply for a patent, perhaps, losing the advantage of months in establishing your date of application. But if you apply for a patent, you at once establish this important date, and you can keep your application alive for an indefinite period. Your application is kept secret, and the first money spent is invested in the operation of getting a patent. Time and money spent on a caveat do nothing in this direction.

When an invention is made, fix at once the date of invention. A sketch dated, signed by yourself and by one or two witnesses is excellent proof. It may be needed in interference proceedings or in patent suits.

CHAPTER XVI.

Original Investigation.

QUALIFICATIONS REQUIRED FOR ORIGINAL RESEARCH —USELESS THEORIZING—INCOMPETENT THEORIZERS—ORIGINALITY—PUBLICATION OF RESULTS—WRITING PAPERS.

The primary lesson of this book is contained in two words—Be practical. Every one's life should be so, and as it fails in this, failure in everything follows. The scientific life should be guided by a gospel of work. The most abstruse mathematicians and theorizers, in the eyes of those without proper insight, seem not to live up to this ideal, but they really do. No man's work has borne more practical fruit than Clerk Maxwell's mathematics and Sir William Thomson's investigations. The latter, to be sure, is a rare combination of the mathematical theorizer and mechanical constructor. His apparatus is in use in the finer operations of the science. His name will for many years be uneclipsed by that of any successor.

But just in proportion as it is useful and proper for such men as those mentioned to investigate the luminiferous ether and to evolve theories of electricity, so is it useless and improper for those unqualified by

Yours truly
William Thomson

genius and study to spend their time theorizing. This is no idle remark. There are numbers of people who consider themselves thinkers and who waste their energies on envolving the most absurd and useless theories. They will formulate a theory that the sun is not hot, that gravity must work in a closed circuit, that the earth is a dynamo, and so on. Sometimes their theories may be half true. Sometimes they will be quite absurd. But one prevailing characteristic is noticeable in all of them—their utter uselessness and inapplicability to any useful end. One of the favorite questions is this: If a gun were fired in the Desert of Sahara, where no ear could hear the report, would there be any sound? Of course, whether there would or would not be, depends on whether we use the word "sound" in its subjective or objective sense.

An example may even be found in the higher schools of science. In physics the advocates of the corpuscular and undulatory theories of light engaged in the fiercest possible contests with each other during the last century, and in geology the plutonic and neptunic schools waged war also. If, instead of devoting their energies to fighting, all had united in humbly seeking the truth, science would certainly have been advanced.

Therefore be slow to theorize. Study facts, work out analogies to fix more firmly on your mind how electricity acts, but do not make the sustaining of some absurd theory and the boring with it of all

your acquaintances your mission in life. You are working in a field of which little is known and of which we may never know much. Electricity is almost as great a mystery as gravitation. There is the more reason why we should be slow to consider ourselves the ones destined to surpass the greatest intellects of the world and to tell mankind what electricity is.

This particular subject is considered so hopeless that a disposition on almost any one's part to determine what electricity is marks such a person for avoidance. Incompetent theorizers, men who truthfully will say that they know nothing of chemistry, and who next proceed to evolve fruitless ideas on electricity, are the unclean beasts of the profession.

Somewhat the same may be said of independent investigators. Work away at original things all you wish to. Nothing is better. But distrust its novelty. It is astonishing how hard it is to find a new line of work in science. So much has been done that it is ten to one that any particular ground has been covered. Sometimes the records are buried away in the files of a journal and are forgotten. When an apparently new field is entered, it would often be advisable for the investigator to look in books and also to run through the files of some electrical journals, to determine whether his ideas have not been anticipated. Mortification might have been spared some of our best inventors by this course. Thou-

sands of workers have preceded you, and the chances are against your doing anything new. The so-called Napoleons of science, like those of finance, sometimes come to evil ends.

Many, we wish we could say all, of our readers remember the investigations of the Pickwick Club. Pickwick clubs are sometimes still found in the world of science.

In practical, every-day work about an electric station or in an electric manufactory there will be many little improvements which will suggest themselves. But on trial it will be found that the selective processes of mechanics have generally established the use of methods difficult to supplant. Yet this line of independent experimenting should be encouraged. It may lead to something,—its results are easily weighed and valued,—and it gives the engineer's mind more flexibility, and goes to make him more useful than he would be if he trod always in the footsteps of his predecessors. But it is very difficult to gain anything by leaving those footsteps.

When by original work, and what is tolerably certain to be novel work, something has been done, it should be published. A young man should start early in the publication of what he has done. The practice of submitting one's self to the judgment of mankind by putting one's self in print has much to commend it. But the greatest discretion and caution must be exercised.

Be a member of an engineering society. Read your paper before them, so that a small audience of qualified men may have the chance to tear you to pieces. If what you say seems well received, then you may feel that some basis is established for its publication. When you submit it to the editor of a scientific journal, it may undergo a still more severe criticism. All this is good discipline and good practice. But if self-educated in the profession, it will be a long time before you will reach a point when you will care to publish your work.

What has been said is intended to inculcate caution in theorizing for your own sake as well as for that of others. If you do want to exercise your brain, do not try to evolve a theory for so recondite a subject as electricity until you can tell why an apple falls to earth.

You must, before you write a paper, know something about composition. For your purposes there is one golden rule—Be simple. In ordinary, every-day English you will find enough words for all ordinary purposes of expression. In addition you will have to use technical words, but that is aside from the main question. But do not invent words, as if the Century Dictionary was not big enough,—avoid all singularities of construction,—do not try to write like Carlyle nor even like yourself. Simply think out what you have to say and say it simply.

A confusion of statement indicates a confusion of

ideas. Let your writings prove that your mind is in good order.

There is great difficulty in putting anything into writing as it should be done. Merely to express to us our own thoughts in the best possible language is high art. If you do propose to write anything for a society or for publication, have your thoughts and ideas very clear and well defined. Then put them into simple language. Avoid too long sentences. The jerkiness of short sentences must also be avoided. Do not use too many adjectives; you will secure strength of expression by the use of nouns. "The adjective is the greatest enemy of the noun, though it agrees with it in gender, number and case."

This is no treatise on rhetoric and composition, but one good rule cannot well be omitted. It is this: When you feel that something which you have written is unusually fine and well put, let it stand until the next day, and then remorselessly scratch it out. Your satisfaction with your own writing is a strong proof of its bad quality.

CHAPTER XVII.

Success.

THE RACE FOR MONEY—THE NOBLER LIFE—THE END FOR WHICH WE ARE ADAPTED—HONOR AND HONESTY—THE HUMAN ELEMENT—DIRECTORS AND EXECUTIVE OFFICERS—THE BUSINESS MAN—DEALING WITH VANITY—RINGS AND CLIQUES—CONTRACTORS—OVER-SCRUPULOUSNESS—WORKMEN.

Success is the goal of the ambitious young man. He perhaps takes up this book hoping that it will help him to the coveted end. But what does he account success? If it is simply money that is desired, a very low ideal is created, and it would be a poor recommendation for our efforts, under the circumstances of the professional life of the day, if it did point out a royal road to fortune. For if one examines the conditions of the world, he will find that men seek different things. Many start on the race in life to make fortunes, but this division rapidly thins out, and some of its members drop out into more or less contented mediocrity. Others continue longer in the race, and devote all their energies to win it. Still the dropping-out continues as weari-

ness seizes those who make no advance, and the few continue. Among these a separation presently takes place. A few begin to approach their ideal, and leave behind them a division who, in spite of ill-success, still keep at the weary grind, stepping on a tread-mill that never raises them from the level. The winners, and they are very few, grow rich, and, it is to be hoped, have got all the enjoyment they expected out of their wealth. The losers, never having accepted the rest and even contentment of mediocrity, suffer the miseries of defeat, and look back on a life of fruitless struggle.

This is a mild picture of the evils of the thirst for money and for success based on money making. The vision of the crowd starting on their race is not a pleasant one,—the scene at the end where the triumphs of selfishness are seen in contrast with the disappointments of selfishness is as bad,—the scenes along the road where the crowd is constantly thinning off, and the competitors only give up because they have to, is not inspiring.

So much for those to whom money is everything. Theirs is not the only contest; there is a nobler race —a race for success, too,—but this is the success of a true life, rightly led and well employed—a life into which troubles will come and in which a fortune may not be made, but which leaves behind it a memory of work, of honesty, and of the refinement of honesty termed honor. Such a life shows good done to the

world in its administration of scientific knowledge—good in its high conception of devotion to "business," as pictured in the character Caleb Garth in George Eliot's novel "Middlemarch"—good done to individuals in the proper carrying on of engineering works in which numbers of laborers are employed—good done to the profession in the making of useful discoveries and in the announcement of them to the public as soon as made.

The contemplation of such lives is a comfort and an inspiration. Energy, laboriousness and conscientiousness are their foundation-stones.

Perhaps among those who read this book will be some who have the high ideal of success implied in the ambition of becoming a Clerk Maxwell or a William Thomson. If such ambition has seized any one, and if he is able to carry it out, he is not the one for whom this is written. This modest work is not designed for him,—his success will not depend on the author.

Finally there are many who simply hope to find a rational chance in the struggle for existence, and who wish to make their living in the profession, and who do not aspire to great honors.

So it appears that from the beginning men can be classified by the end they have in view. The sad failures come in choosing the wrong ends,—the criminal failures in choosing wrong methods for any end.

A man might choose to be a high jumper, and

might devote the energies of a life to trying to top a six-foot bar, and never succeed. His failure would be due to the choosing a wrong end.

Suppose now that we cut the Gordian knot and at one sweep do away with this trouble about ends. Select no end to be attained, but only concern yourself with methods and practices. The trouble disappears. With honor and hard work as watch-words, whatever you do will be successful, whether the crowd appreciates it as such or not.

You will see men going ahead of you by questionable methods,—honor will prevent you from envying them. You will see others going ahead of you by superior work,—interest and a high ideal will tell you to follow their example and work the harder. You will see others winning by high abilities,—these justice tells you to admire. Then as you reach the middle point of your career, and are retrospective, you will realize your mistakes ; you may feel that had you taken some other way you would have done better ; you may see instances where a little shrewdness and knowledge of human nature would have helped you along ; you may feel that you should have done better ; but it will be too late. Regrets are useless. Go on as best you may, and if you can feel that you have saved your honor and conquered your laziness, you have not lived in vain.

This seems a poor ideal, perhaps, but it is better than money making, pure and simple. It is hard to

believe that you will really work hard and honestly and not make some success.

But as an electrician and electrical engineer some few maxims for success may be given as regards your relations with men. As the servant of corporations you will have intercourse with directors and business executives. As engineer you will have to deal with laborers and foremen under your superintendence. You will find rings and cliques among the wealthy directors and among the day-laborers alike, and you may be mixed up with their cliques, without any volition on your part. You will come in contact with manufacturers and perhaps have to criticise their work. How can you deal with such different types of humanity?

Human nature therefore must be recognized as an element in the problem you have to solve. For a wealthy business man to be established as president of an electric manufacturing works, while not conversant with electrical matters, may seem to you an anomaly. It will seem that a merchant should know something of the article he deals in. But while on its face this would appear to be logical, it is not absolutely requisite that the merchant should possess such knowledge. The business of the president of an electric manufacturing company may be to sell the product of the factory, to see that its standard of perfection is kept up to, to look up new avenues of trade. The selling has no reference to volts and

ampères,—the standard of perfection he takes care of by engaging one whom he understands to be a capable superintendent,—looking up new country is a matter of advertising and traveling. The less he knows of electricity, and the less interest he shows in the science and in the materials used in the dynamos, the more flattering is it to his superintendent. The want of interest in the electrical qualities of the wire purchased, the ignorance of what the magnetic properties of iron, such as reluctance, are or mean, and the apparent indifference to what goes into the dynamos are due to strong common-sense. He realizes that it is a new order of thought for him, and so does not try to grapple with it. He feels that the products of his factory will be criticised by those who buy them, so that, whether he wants it or not, he will get lots of expert opinion without cost or trouble. Knowing that he cannot adequately criticise from his own knowledge, he will be unsparing in his use of the free criticism reaching him in the shape of complaints of customers. Therefore, if his superintendent or engineer wishes to impose upon him, and is so wanting in pride and honor as to stoop to this course, it will be found a very risky business. Active and successful business men in this country are apt to be rather merciless in dealing with transgressors subordinate to them.

Often men of this character have an aggravating way of throwing aside as of no interest all that does

not directly affect their business. This peculiarity must be recognized and yielded to. Commercial interests are apt to engender selfishness. If you are an engineer under such a president, realize that he has his good points,—that he is interested in things that are as barren to your mind as are farads and henries to his. Above all, do not be so conceited as to underestimate the merit of high business abilities. Your little special knowledge of electricity is probably nothing to boast of. Do not try to look down on a non-professional man ; his abilities and specialties lie in another direction from yours.

The very qualities which make a man an electrician by nature would probably spoil him for a business man. So look with respect upon the great organizers of enterprises—those who deal in great interests, and who have no disposition to look into the minutiæ of things, who would distrust themselves if they did go into manufacturing details, and would fear that the result of an attempt at doing so would lead to neglect of important things in their department. Your very fondness for details, and disposition to give your principal attention to them, feeling that the generalities will take care of themselves, is exactly what is not wanted in business.

Human nature has its vanity, and it is often manifest in a disinclination to acknowledge our own ignorance. Sometimes a business manager or other officer of a company, whose life has been spent in mercan-

tile pursuits, will undertake to pose as an electrician after a few months or even weeks in the business department of an electrical concern. This is far worse than the other case first described. How must such be dealt with? It is not necessary always to tell a person how little he knows, or to offend his innocent vanity by pointing out his errors. It is enough to try to lead him right, as far as he will let you. His way may be smoothed for him if he will stand it. Avoid disputes with such,—disputes will do no good, and will only make trouble between you and your superior. So study human nature a little, and do not get into fruitless discussion; try to keep your own specific knowledge in the background if necessary, and do nothing to show how much you know. If you are dealing with what appears to be a very pretentious person, temper the wind to the shorn lamb, and do not be too hard on him. His position may give him the power of being very hard upon you.

Independence is not sacrificed by such a course. It may be rather a matter of courtesy and kindness that will induce one to be careful not to hurt the feelings of another in such a case as the one pictured above.

Companies are often supposed to be managed by a board of directors who meet from time to time to discuss its affairs, and pass resolutions as required for its conduct. While they nominally are the directors who direct the company, usually there

is one person, either an officer or perhaps only one of the board, who is the real manager, and who is practically the whole board in one. Directors are often fond of exaggerating their importance to the concern,—they often like to persuade themselves that they are of some use, when they are not. Again you may profitably study human nature. If they visit the works where you are employed, do not try to show how little you care for them. If you meet them, remember that your profession makes it your first duty to be a gentleman, and that nothing is more alien to a gentleman's character than conceit or intolerance. These directors are apt to be men of standing in the community, and often men of high ability in their own particular ways. The ethics of your profession tell you to bow the head before such masters as Thompson or Rayleigh,—they do not tell you to put on airs of importance before those whose paths in life lie outside of the electrical field.

Unfortunately cliques and rings sometimes are formed in companies. The engineer or superintendent is not to take sides if he possibly can help it. If there are two factions who try to obtain the mastery, there is a strong probability that, if the engineer or superintendent is drawn into the fight, he will find himself between the upper and nether millstones,—he will be apt to please no one if he makes special efforts to please both sides,—and the end may be the loss of his position. If he takes sides and his party

is defeated, he need have no uncertainty as to his own future. If his party wins, then his too strong advocacy may bring about his discharge.

An engineer in such a case has a narrow path to tread, and his only rule must be to hold himself absolutely aloof from dissensions. This he must do without withdrawing himself from observation or seeming to avoid contact with those in the dispute. If an officer visits the works, the superintendent should act precisely as if he knew of no dispute. Without committing himself he should meet his visitor and act as if everything was normal. The next day some director opposed in interest may appear. He should be received with the same courtesy. Thus neither side can be given just cause for offense, and whatever the result of the supposed dispute, the superintendent may be glad if he can feel that he is not involved.

A difficult case has been described, and it is to be hoped that our engineer will be spared such eventuality. But he may become involved in it, and if he cares about retaining his position, he will feel justly anxious.

Another class of persons he may encounter are contractors. It often happens that such people have great influence with corporations. They may do work for them and take their pay in stock, thus getting a large representation on the board. The officers of the company may have leaned on them for advice

and consultation, and so may place great reliance upon their opinions. You may, as engineer, have to pronounce judgment upon their work. Here again you may find yourself between two fires. If you do not approve the work, you may incur the ire of the contractor, and suffer. If you do approve the work in order to avoid trouble with the contractors, you may be doing an injustice. It is better to suffer the loss of your position than to do the latter. There is always a probability or possibility that such a sacrifice may be exacted by your conscience. The sacrifice, if made, will be its own reward ; you need not expect any other. It will probably never have its merit recognized except by yourself and perhaps by a few fellow-sufferers and companions in misfortune. So what are you to do in such a case?

No general rule can be given. You must be conscientious. But sometimes there is danger of supererogation. You may go unnecessarily far. The least display of feeling or eagerness to condemn is wrong and out of place. With absolute dispassionateness review the work and form a just judgment. If your position requires you to report upon work, do so with entire absence of feeling, and, with as little comment as possible, state how things are. Do your best to avoid giving offense. Let it be seen that you have no bias and are only doing your duty. Then if the contractor takes offense, and is dishonorable, and has influence with the company, you will have to suffer. There will be no help for it.

But be very cool and act slowly. When you look back on the affair after the lapse of years it is to be hoped that your course will still seem to have been the right one. Do nothing on impulse, and do not set your own standard of right and wrong above that of every one else. It is often not only a matter of conscience but of judgment. An over-scrupulous man is often very unsatisfactory, because his judgment is in abeyance under the weight of his conscience. The conscience of an over-scrupulous person is little better than conceitedness.

If you do feel scruples about the way of dealing conscientiously with such a case, consult some friend. Do not shut yourself up in unhealthy introspection, but seek advice, and use it. Whatever you do, you will have a good chance of pleasing no one. If you leave the company in what seems to you a blaze of glory, you will be apt to find its brightness diminished after the lapse of several years.

The engineer has to manage workmen. These are also human beings, and are as clique-forming as any set of men—even as much so as the directors of a company. But their methods will not be apt to affect an engineer's position. As he therefore feels secure from the influence of what these subordinates can do, there is the more need of exact justice and charity in dealing with them. There is not for a real man one bit of satisfaction in discharging a workman for a purely technical offense, or even for

a slight impatience or incivility. Your pride should be in the small number of workmen you discharge for cause,—your pride should be hurt by a large number discharged. You should feel that this latter shows you a poor manager of men. Avoid despotism as you would a disease.

You may have absolute authority,—you should practice the art of exercising it to the fullest extent when necessary, and of concealing it at all other times. Workmen spend much of their spare time and thoughts in sizing up their superintendents. If you have authority in your nature, they will soon find it out.

An engineer need not be so sensitive about his own authority as to be unwilling to recognize some rights on the part of or some respect due to officers of the company in the placing of men. If a workman is put in position at the request of the president or of a director, courtesy requires that he be consulted before such a man is permanently suspended.

Workmen, being human, will often try to earn their money as easily as possible—something their employers also try and generally succeed better at. But they are hired to put in so many hours' work a day, and it is the engineer's duty to see that they do it. A man running a machine lathe at slow speed so that he can sit in a corner a longer time between the settings of the tool for a new cut would do no worse if he went away half an hour ahead of the

whistle. A man who runs a tool with so dull a point that it takes twice as long to put a finish on his work as if he ground his tool properly is doing his employer an injustice.

It is very hard to get good workmen. Men are, on the average, of such low capacity that it does require about seven years to make mechanics of the average ones. Therefore, with the abandonment of the system of apprentices, the supply of really good workmen is less than the demand. We are becoming more accustomed to having work done poorly or slowly in our factories, the really good mechanic not being as easy to find as he formerly was.

CHAPTER XVIII.

Reading.

ENGLISH TECHNICAL BOOKS—THE INDEX—READING A BOOK SEVERAL TIMES—THINKING—READING AN INSTRUMENT—TAKING NOTES—ELECTRICAL JOURNALS—RANGE OF READING—DEFINITIONS—COLLECTING A LIBRARY — SCRAP-BOOKS—CARD AND BOOK INDEXES—SCRAP-LEAFLETS — RAPID READING—BIOGRAPHIES.

The subject of reading cannot be adequately treated. So much may be read ; every book, even if it seems a repetition of some work already read, will add something to the reader's stock of information. The list of electrical books is increasing constantly. But among the many a few standards still maintain their position and stand well above the rest.

Many technical books in our language are published in England, the scientific literature of which country is unfortunately subject to a very serious fault—one which permeates the life of the nation in other directions also. England has an organization of examinations for degrees. The effort of her educators has been to codify education, and to make all the colleges tributary to certain standards.

Accordingly, examinations in every conceivable branch of knowledge are held at intervals, and to these come students from colleges all over the land as well as students who have not matriculated from any college. They are competitors for degrees; their work has been distinctively devoted to passing examinations—"exams," as they term them—and their scope or range of study is calculated to fit these examinations. For such students many of the scientific books are written. Students and books alike are stunted by the system.

When you take up a scientific book published in England, look at the title-page. If you there find stated that it is written for or adapted for some degree or course of the London University, if the word "syllabus" occurs on the title-page or in the preface, make up your mind that it will have a very fixed limit. It will be written entirely for a certain examination. Anything outside of the lines, however important, will be omitted. Such books should be looked on with suspicion as to their value here.

A scientific book should have an index. When you think of buying a book, see if it has a good index. If it has none, then leave it. A contents is better than nothing, but cannot usually take the place of an index.

A good book read and reread may do more good than several different ones read in succession. At the beginning, especially, it is often useful to read the

same book several times. The real classics of the science will endure several perusals and improve with acquaintance. A good test of a book is to see if it will endure this. If you drift back to and reread a work, it speaks well for its quality.

Thought and reading must go together. It has been said that an hour of thought is worth many hours of reading. This is often true. Nothing is more futile than to read to the exclusion of thought. It is often a form of indolence—a way of hiding one's own laziness. What we have read during several hours may be briefly thought over to good effect. Acquire the habit of thinking intensely over facts that your reading has brought before you. Think over what you read until you detect the weak points in your knowledge, and try to supplement these points by further reading.

Treat reading as an instrument. It is a means of reaching a desired end,—mere reading is not the end. You must not feel undue satisfaction in having read so many books or so many pages. Your satisfaction should center in the ideas you have assimilated and have taken from the books.

Should one make notes of their reading? This depends on the individual. If you have the proper type of mind, you will need comparatively few notes. Like the hero in Charles Reade's novel, "Put Yourself in His Place," make your head your note-book. A man who has to write everything down is at a serious disadvantage.

You must learn the art of quick reference to books. A library of half a dozen books will be a good one for practical use. You must learn their uses and range, so that you will know in which one to look for anything you want to find. It will be excellent practice to look up other books than your own, and study the ground covered by them. Thus you in some sense make their contents your own property,—you know what each one is good for.

The electrical journals should be read. One is enough if it is of the best. The advertising pages should be run over as well as the reading matter, for they tell what the world is doing.

The reports of the meetings of electric light associations and other societies of electricians are excellent matter. They not only contain good information and valuable papers, but they also disclose what others are working at. They give a standard for rating one's own attainments, as in the papers and discussions is shown what other electricians are doing, and how deep they go into the science.

It will not be necessary to keep your reading rigorously to one line of electrical work. You may in one book often with benefit go over an elementary treatment of the whole of electricity. As a guide to your work your reading of course will be more specialized.

Your reading must cover more ground than electricity. You will have to be a mechanical engineer

in the broad sense, which is the sense of knowing something of chemistry and physics, much of the strength of materials and machinery, and much of calculations, graphic, arithmetical and algebraical. Your reading, therefore, must cover a wide field. Yet if you could be persuaded to do one thing, your list of books might be small. This thing would be to thoroughly understand and assimilate everything you read. It is perhaps too much to ask. Then try another system. Thoroughly understand and learn the first book you read on a given subject. Let such book be short, but when you are through with it know it. Know one book in arithmetic, one in algebra, one in mechanics, one in physics, one in chemistry; pick out short ones, and you will have laid a foundation which you may congratulate yourself on for years to come.

Under the head of reading a few words should be said on definitions. A good definition is something to cling to. You will find them all too scarce. An excellent plan would be for you, when reading a book on a given subject, to learn by heart the definitions of even three or four subjects intimately connected with it. In physics *work*, *energy*, *force*, *momentum* and *weight* are such subjects. In chemistry *element*, *molecule*, *atom*, *molecular weight*,—in mathematics *exponent*, *radical*, *logarithm*,—these may be taken as examples. Electricity as your specialty should give you somewhat more definitions.

Unless you have a very retentive memory, write out these definitions as you learn them. Do not let writing take the place of memorizing, but write them out and preserve them. Then from time to time return to them, and you will find that they serve a very useful purpose, presenting a skeleton upon which your structure of facts will be carried. They will act as a sort of *memoria technica* for your reading. Your constant recurrence to them during your reading of physics, for instance, will make them bring back to you the work of the hours you have spent over it.

Remember that it is precisely in exactness of definition that modern science surpasses the old. It is but a few years since a book was published in New York devoted to the supposed great doctrine of the conservation of FORCE. The truth is, there is no such law; for years it was preached at us; poor Faraday felt that it was wrong, but with graceful humility bowed to authority and accepted it. So this conservation of force was kept as a great doctrine of science until scientists learned to define—learned what force is, and that it is not immortal—learned what energy is, and that it is immortal—and threw overboard the absurdity that disturbed Faraday, and which was quietly accepted by many lights in science.

Books are expensive. Ruskin would have a man begin early in life to collect his library. He de-

spises circulating libraries. But you should only go half-way with him. Collect your library, and it need only be a very small one, but use circulating libraries to the best of your opportunities. They are especially to be commended for providing scientific journals. A dozen books supplemented by intelligent use of a library—circulating, society or college collection—will carry you a long way.

Owning but a small library, you will be in a fair way to know the books composing it thoroughly,—and this thoroughness of little knowledge rather than thinness of much knowledge is the sermon which this book is designed to preach.

As just suggested, the leading electrical journals may be read or looked over each week. It is well to have the best of them your own and at your disposal. But often in the daily papers, magazines and elsewhere, little notes of interest electrically are encountered. Certain data, such as resistance and voltage of different arc lamps or batteries, will be seen in electrical journals, or, perhaps, will be specially ascertained for some purpose. It is a pity to let such matter escape. Scrap-books or leaves are the proper repository for them.

With scrap-books every one is familiar, but it is not one in a hundred that arranges them systematically. The best way, all things considered, is to paste in all cuttings, or write in any important item, without any attempt at order.

The next thing is an index. This may be made on the card principle if the book assumes size enough. Or, if the scrap-book is small, a good contents and a complete index for it can be written. It is not necessary to make the alphabetical division go further than the first letter. Thus all the A's can be grouped together in the order they come in, and the same can be done for all the other letters. If you make a card index, then you can, as one scrap-book after another is added to your list, simply keep up the index, the one answering for any number of books.

If you start a card index, you may very well include in it references to important points treated in books. Thus under "*curve, characteristic*" any number of references to books could be given. This practice would obviate in many cases the writing of notes in the scrap-book, for of course it will not do to destroy books by cutting scraps from them. A good practice, if you wish to carry out this idea, is to carry a dozen cards with you when you go to a library, or have them near you when reading at home, and enter on them any references which it seems likely will be useful. A fountain pen of the anti-blotting kind is useful for this sort of work.

Study to use cards only for really good references; do not put down indifferent things, or you will run into the danger of becoming a card collector only, and have no time for anything else. The card index must be servant, not master—a means for an end, and not itself the end sought for.

The handwriting for cards should be clear and good. Every one must be written out very carefully, as bad writing will disfigure the collection greatly. A very open back hand is excellent.

Scraps may also be preserved on leaves. For this purpose a quantity of sheets of paper cut to uniform size and of good quality for being pasted on is required. A single scrap or cutting, or more than one of very closely related scraps, go on a single sheet. Only one side is pasted on. Holders for these are made by doubling a piece of brown paper a little over twice the size of the leaves. The latter may be seven by nine inches or thereabouts. Each cover may be numbered, and will hold twenty or thirty leaves. Each sheet is numbered individually, and is marked with its cover's number. A general index gives the desired reference to cover number and sheet number.

Another way is to put a title on each cover and put into it scraps coming under such title, which must be quite a general one. In this case an index may be made for each of the little portfolios.

There is one trouble with scraps. They are apt to lose value year by year. The information contained in them either becomes antiquated and useless, or it becomes so well learned by frequent reference, that you need no scrap-book reference. This is merely one development or phase in the art of carrying your note-book between your shoulders.

The best advice would seem to be this—to collect scraps or to make up an *index rerum*, as the general card index may be termed, always with the exercise of great discrimination, and to collect and note rather too little than too much.

The *index rerum* or card index of things may be made to apply to everything you do. When working at experimental chemistry you may encounter interesting points. These may be referred always or almost always to some part of the text-book or of some book on chemistry. Then the insertion of a card reference to the text-book in the index will fix the fact for future use. Thus a book is made subsidiary to chemical work, and supplies the requisite for indexing your work. Your own private notes are apt to be of little value until you advance pretty far in the profession. Refer if possible to books.

There are two ways of reading. One is to cover as much ground as possible. Every book is more or less diffuse, and much can be skipped. Unless you feel that you have a very vigorous understanding and analytical powers, a dangerous liberty will be taken if skipping is indulged in. The best parts may be lost, or by being gone over so lightly may fail to become fixed in the mind. Here a distinction exists between reading and studying. The latter should aim at completeness in degree, not so much at extent to be covered. But reading may vary in amount done according to the topic. It is futile to read

some books rapidly. They have to be studied almost word for word.

As one advances in any study, reading can be done more rapidly. A good rule to begin with is to read slowly and carefully. After good advance has been made in the science, selective or discriminative reading can be indulged in ; in other words, one can take up a book and skim through it, going lightly over the parts not directly appertaining to his wants, and giving more attention to the sections of most pertinency.

Perhaps the plan of this book may permit a slight digression here in favor of some biographical reading. If you wish to learn the gospel of labor from the best preachers thereof, read some biographies. Read the lives of such men as Faraday, who could have made a very large fortune in his profession if he had confined himself to commercial work. With such a prospect before him, one which would ordinarily be called brilliant, and which is known to have been of a nature to excite the ambition of almost any one, he voluntarily relinquished it, and elected to devote himself to pure science. This he did for the rest of his career, and so made himself a benefactor of the human race. It was a sacrifice, and a noble one.

Read the beautiful life of Clerk Maxwell, and see how his mind from earliest youth was of a mathematical and scientific bent. The story of his amicable

CLERK MAXWELL.

nature and happy disposition joined to profound mathematical abilities is of the deepest interest.

Other biographies of great scientists preach the same gospel over and over again. It is work always that tells—all were workers. Newton, Davy, Henry, found no royal road to success and fame. All they got was the fruit of hard work and of hard thinking. They are your examples. Hard thinking helped them. They had hardly any library of reference books to appeal to; they had no luxury of reading such as the present generation enjoy. Learn from them that thinking as well as reading is work, and that to be worth anything it must be thoroughly done.

So do not let reading supplant thinking; do not let reading prevent you from thinking for yourself,—rather let reading be the incentive to thought.

Besides biographies there are books which contain anecdotes of the world's thinkers and workers, and these will be interesting reading. Such a book is Smiles' "Self-Help."

From biographical works and those containing personal anecdotes inspiration can be drawn. If they only teach that an uphill road is before you, that the best and greatest of mankind had to climb it step by step, that there is no easy way to a true knowledge of science, that unceasing work was the life and delight of the great ones of the world,—if this much is taught by such books, read them.

They should have one of two effects; they should

frighten you out of science, something which may be very desirable and conducive to your own good; or they should cause you to enter the portals of science with a determination to be a slave for years.

You probably will not be a slave. You will make your living and may even be a successful electrician without such labor,—but with labor you will be a successful man.

An inveterate reader is often one afflicted with a peculiar form of laziness. You must be a doer, and reading must be a means for the end of doing. So for you to boast of having read so many books in a year may indicate a defect, not a merit.

CHAPTER XIX.

ETHICS.

PROFESSIONAL LIFE—THE GENTLEMAN—TRUTH, JUSTICE AND HONOR—EXAMPLES OF SUCCESSFUL LIVES — BRUSH — DOLBEAR — GÜLCHER — LODGE —PACINOTTI—ELIHU THOMPSON— CONCLUSION.

Every life has its specific rules of action in its relations to the rest of the world, which rules may be comprised under the heading of ethics. These are the rules of honor and propriety, which tell us what our profession calls on us to do in certain cases.

Without preaching a sermon it is hard to speak of ethics. It must, however, be attempted. Perhaps in this connection the reader may be willing to go a step further and to accept as commentary on the ethics of professional life the early history of a few distinguished scientists. They can act as a conclusion to what precedes, and justify some of the views which have been taken. Examples could be multiplied indefinitely, for the biography of scientific men is full of such lives as those noted below.

Be a gentleman. This is the first advice to be given to any one in any position in life. But here you are entering the profession which embraced or

embraces in its ranks such men as Faraday, Clerk Maxwell and Sir William Thomson. You are to be in their company hereafter,—act as if you were in the presence of the true "immortals," who have created the science of electricity.

Be true. If you have for months thought over an idea and worked up some invention only to find that it is useless, abandon it. Do not try to deceive any one as to its value. Be truthful even to yourself, and do not let self-interest persuade you that anything is right which is not, or that anything has value which has not. Many a promoter of worthless enterprises satisfies his conscience by first getting it persuaded of the worth of his schemes; then he can mislead others with less trouble of said conscience.

Do not be obstinate. From lowest workman to the least scientific business man whom you come in contact with, every one can tell you something. If a pay-master teaches you to count money rapidly, you have learned something. The coal shoveller can show you how to pick up the last bit of coal from the floor by the quick jerk of his shovel. Do not be too obstinate to learn from every one. If in the wrong about anything, be quick to see and acknowledge it, and learn what is correct as soon as possible.

Be just. If you have achieved an important result aided by others, give them due credit. Never be guilty of the meanness and injustice of absorbing the results of another's work. Here we are brought face to face with another motto, namely:

Be honest. An invention is the property of the maker, unless by special contract it is otherwise determined. A stolen invention when patented implies not only injustice and stealing, but also perjury, for a patentee has to take a solemn oath that he was the original inventor. Never take a commission for influencing the purchase of goods by your employer, whether individual or company. If you do, you will make yourself the slave of the person whose goods you have recommended, and will place yourself in his power. Act purely for the interest of your employer. You will lose no money by doing this,—you may lose the making of money by it,—but between these two things there is a wide distinction.

Charles Francis Brush stands as one of America's foremost electrical engineers. Born in 1849; in 1862, when thirteen years old, he began experimenting with batteries and magnets; two years later he took up the construction of microscopes and telescopes, even grinding the lenses himself. Induction coils and electrical apparatus for turning gas on and off, and lighting it in street lamps, were part of his work at this early age. He completed in two and one-half years the regular high-school course ordinarily requiring four years, entered the University of Michigan, and graduated one year ahead of his class. Here we see the boy emphatically the father of the man.

Professor A. E. Dolbear of Tufts College, who in inventing the telephone ran a close race with

Alexander Graham Bell, while working in a pistol factory, took up electricity at the age of seventeen. He afterwards became a school teacher, then entered a locomotive works, and at last, when twenty-six years old, managed to enter college, having prepared himself for it by studying in the evenings while working in the Springfield Armory. He graduated at the age of twenty-nine, years older than most college graduates. While an undergraduate he invented a magneto-telegraph.

The life of Thomas A. Edison tells of long nights of labor. When a boy he practiced telegraphic operating assiduously, sometimes all night. When his chance came he was prepared to take full advantage of it. He was only a boy when he invented his automatic repeater.

R. J. Gülcher of Austria, one of the leading electrical engineers of the Continent, when but twenty-three years of age was in charge of a small machine-shop in his father's cloth factory. Three years later he made it grow to be a large iron foundry and machine factory. In 1878 he bought a three-lamp lighting plant of Siemens & Halske. He had some trouble with the arc-lamp regulators. This started him into electricity. He invented new lamps and dynamos, and elaborated the circuits of distribution. He is sometimes termed the inventor or discoverer of the method of dividing the electric light.

Professor Oliver Lodge went into business with his

father at fourteen years of age, and remained so for some years. Now and then reading an "English Mechanic," or an article in the "Penny Clyclopedia," we find him attending finally a course of six lectures by Tyndall, and his latent scientific bent was aroused. He took a private course in elementary chemistry. Evening classes in chemistry were next attended. At last by working at odd hours he managed at the age of twenty to enter the London University course, and four years later got his degree of B.Sc., and two years later he was made a Doctor of Philosophy. Here again is a story of night work and of struggling upwards through the greatest difficulties.

Antonio Pacinotti, nineteen years of age, built a motor with a ring armature, antedating the Gramme ring. His invention is cited often, and the Gramme armature is often termed the Pacinotti ring.

Elihu Thompson at eleven years of age made a frictional electric machine from description only, never having seen one. All through his school period he worked at mechanics and made apparatus, using the crudest possible tools. He made many pieces of electrical apparatus, batteries, etc., and graduated from the high school at seventeen years of age. After this he constantly made apparatus of all kinds, while acting as assistant professor and professor in the same high school. His splendid achievements in electrical engineering have since these early days won him world-wide fame.

The lives of such men are a commentary on this book. In them we see an early taste for science ; in boyhood they invent or construct scientific apparatus. The days being necessary for them to earn their livings in, the evenings or whole nights are devoted to study and work. They go on, and win their position. Some reach high positions in mathematics ; some study chemistry while little more than boys ; some become engineers. All do it by a devotion to science and by hard and unceasing work. Some have no teachers ; others with meager enough education supplement it by work in the night schools, or by attending science lectures. The few lives noted are but a sample. The engineering ranks are full of such men.

APPENDIX.

THEORY AND PRACTICE.

The student, if he has had some actual experience in the shop or office, has undoubtedly heard allusions made to theory and practice. He has most likely heard them spoken of as though they were distinctly opposed to one another—as though a theoretical man could not be practical nor a practical man theoretical. Much of this talked-of antagonism existing between theory and practice is the result of a misconception of what "theory" really is, and in using the word "theory" when "hypothesis" is what is meant.

A hypothesis is "an imaginary state of things assumed as a basis for reasoning."* The various ideas advanced as explanations of electricity, gravitation and other natural mysteries are all hypotheses.

To be sure, a hypothesis will explain phenomena to a certain degree, but experiment will surely bring to light many manifestations of these forces which the hypothesis must balk at.

How different from this then is theory, which "agrees with all the facts and disagrees with none."*

* Standard Dictionary.

Theory formulates and tabulates the laws which are derived from a study of the facts of phenomena as developed by experiment.

Theory provides the necessary data whereby a practical man can design a machine with a certainty that it will, when built, fulfill the requirements for which it was constructed.

Examples of such calculations are seen daily in the structure of dynamos, engines, cranes, bridges, skyscrapers, etc.

It often happens, to be sure, that a theoretical man may not know enough of machine shop practice to design a machine so that it can be manufactured at a reasonable cost and thus contribute to its commercial success. In such a case it will be better for him to confine himself to experimental work or to the calculation of essential dimensions of a machine and advising with the actual constructor as to mechanical details.

Get all you can of theory and how it is applied. You do not need to memorize much more than elementary facts, but if you are accumulating a reference library make it your practice to have a good idea of the contents of each book so that when facts are needed you can at once refer to the books containing them and find the table, formula or figure required.*

* See page 167.

AIDS TO MATHEMATICS.

The writer introduces this subject with some hesitancy, fearing that the student will turn at once to it expecting to find it full of guide boards pointing out a royal road to the acquirement of mathematics. As such a road does not exist it will be well to explain that the intention is to indicate certain means for facilitating calculation and thereby saving time and labor.

It must, however, be strictly borne in mind that a good working knowledge of the subject as outlined in Chapter II. is essential to a proper understanding and right use of these useful aids.

The simplest form of help consists of the various arithmetical tables which are contained in the well-known engineers' pocketbooks. Such tables give the circumferences and areas of circles of various diameters; the squares, cubes, square roots, cube roots and reciprocals of a long list of numbers.

Many other valuable tables are also included, but those just mentioned are the most often used.

Tables of logarithms are also of great value, but have been mentioned on page 32.

The simplest mathematical process for which mechanical aids have been devised is that of addition, but since in the usual calculations of an engineer addition is a very simple matter we will leave such

devices to those for whom they are more especially designed.

The next processes in order of difficulty are multiplication and division. These can be accomplished with perfect accuracy on the adding machines just referred to, but they are done more rapidly by machines specially constructed for the work.

The simplest devices for this work are known as slide rules. These may be had in a variety of forms ranging from a pocket size in a case like a watch to a large cylindrical style to stand on a desk.

The most popular style is a straight rule of about ten inches in length, the middle part sliding, the adjacent fixed and movable edges provided with graduations reading from 1 to 10 with decimal subdivisions.

To most people the slide rule is a mystery. They can understand readily enough how numbers can be added or subtracted by using a sliding scale divided into equal parts, but they cannot conceive how multiplication or division can be accomplished in a similar manner. Just here is where your knowledge of the principles of logarithms will be of great aid, for the divisions on a slide rule are proportional to the *logarithms* of the numbers annexed to them. Hence it follows that by adding or subtracting the spaces on the slide and rule you obtain the product or quotient of the numbers which those spaces represent.

The slide rule is remarkable in being the only mechanical device (aside from tables) which will with but a single motion enable the result to be instantly attained. For example, such problems as

$$\frac{a^2 \times b}{c} = X, \quad \frac{\sqrt{a^3}}{c} = X, \quad \left(\frac{\sqrt{a} \times b}{c}\right)^2 = X, \text{ etc.,}$$

can be solved by merely setting the slide in the proper manner and then reading off the answer from the graduations on the rule.

There is such an immense variety of problems in multiplication, division, ratios, proportions, squares and square roots, etc., which are of daily occurrence and can be solved simply and with sufficient accuracy by the slide rule that every student is advised to obtain a good one with a book of instructions and to practice on it at every opportunity.

As the ordinary slide rule cannot be read to more than four significant figures, those who require greater accuracy and rapid work use calculating machines in which the problem is set up on numbered wheels and the result read directly from other wheels; the mechanism to effect the result being operated by a small crank turned by hand. Lest the student be too eager to acquire one of these luxurious aids I would mention that the Tate arithmometer, an imported machine, sells for $400, and the Baldwin calculator, American made, sells at

$250. Nevertheless, as such machines are destined, like the typewriter, to find their way into every mercantile and engineering concern, it will be a good plan for the student to take advantage of any opportunity which presents itself to observe the operation of such an instrument.

ELECTRO-CHEMISTRY.

Since the first appearance of this book the science and practice of electro-chemistry has grown rapidly, vast plants for the electrolytic purification of copper have been installed, the power of Niagara and other great waterfalls has been utilized in part to generate intense heat in electric furnaces producing carborundum, graphite, aluminum, calcium carbide, etc. Of these substances, carborundum is an entirely new product and aluminum and calcium carbide were hitherto laboratory curiosities of a cost prohibiting their commercial use. There is plenty for the competent electrical engineer to do in the design of machinery for operating such plants as these. There is, too, a large field open to the experimenter in devising or discovering economical processes for the reduction of the rarer metals from their ores, and in other allied lines.

It is of course obvious to the student that a good fundamental knowledge of chemistry is an indispensable preparation for such original research.

DRAWING.

In this branch of engineering only the general principles and the modus operandi can be learned from books. Actual practice and one's own natural dexterity and neatness are the factors needful to success in drawing so far as concerns the merely mechanical work of making the drawing. To achieve success in the designing of a detail or of an entire machine requires experience, knowledge both theoretical and practical, and a large quantity of common sense.

The young draftsman should take every possible opportunity to compare a completed machine with the drawings from which it is built. This is to give him a clear idea of how to read a drawing, and will show also that certain parts when seen on paper often look very much heavier in metal.

In the laying out of the machinery in a central station and more especially in the restricted floor space in a modern apartment or office building a very good plan is to make outline drawings on a stout detail paper of the floor plans of the different dynamos, engines, etc, which form the installation. These outlines must be to the same scale as the plan of the engine room in question. Now by cutting out these outlines they may be placed on the building plan and shifted around until they are arranged to the best advantage. These pieces may

also serve as templates to aid in drawing the machinery in situ.

When the plan is on tracing cloth these templates may be arranged on the board beneath it and traced from.

EDUCATION.

Within the past ten years a new factor has entered the educational field in the shape of Correspondence Schools. These are of all varieties, some even claiming to teach vocal music in this manner. There are several which have a high order of practical lessons in electrical and kindred subjects, and it is to these that this brief section will refer.

The Correspondence School is intended primarily for the self-supporting young man, for him whose circumstances will not permit of his taking a college course or a student's course in a large factory. The correspondence system will benefit the student just in proportion as he is diligent and persistent in working out his studies.

The majority of its students have only the evening to devote to the work; this is of advantage rather than otherwise, for by it one gets not only the instruction, but is kept from the various careless habits and temptations to which the idle are apt to fall victims.

These schools are often of value even to the college graduate or business man, as there may be some

subject he may need to know all the particulars of; a special correspondence course on this one topic will prepare him to deal intelligently with it. As an example of this, take the course in gas engines which is offered by one of our prominent schools; this is a theme on which but few people are well informed and even those who run the engines do not always fully understand their operation. The acquisition of this special knowledge is not a bad investment in these days of direct-connected gas engine and dynamo installations and of gasoline automobiles.

In selecting a correspondence school do not be unduly attracted by offers of free apparatus or other outward inducements, but ask rather to see the complete instruction papers of the course; you can then judge for yourself if the course is one you desire to follow.

WORKING MODELS.

Another useful adjunct in helping one's self to acquire a technical education is the construction, by himself, of course, of some working model of an engine, dynamo, transformer, or other appliance.

Very good sets of parts for a small dynamo or motor and a small gas engine can be had for a reasonable price.

The building of such models pays doubly—first, for the instruction one gets by the work; second,

by the usefulness of the model when made, as for instance, a small gas engine will run a lathe on which further devices may be constructed.

An excellent practice with such models is to enter into the theory of their design so that, taking the gas engine again for example, one should know the area and lift of the inlet and exhaust valves, the proper speed for the given size of cylinder, the length and diameter of the main bearings, cross-section of flywheel rim, etc. Work such as this removes the model from the domain of toys and places it on the basis of sound engineering practice.

INVENTING.

While this topic is pretty generally covered in Chapter XV., yet recent experiences of the writer lead him to deem a few further remarks advisable respecting patents and models.

Although the United States Patent Office does not now require a model of every invention, yet it is generally desirable that an inventor should have a proper working model of his new device. There are several reasons for the construction of such a model; —to prove if his invention be operative and of any real value; to aid his attorney in preparing the patent drawings, specifications and claims; and to present his device to the investor and to the manufacturer.

A common mistake of inventors is to get out their

patent in as quick a time as possible after a new idea enters their heads. As soon as they feel the protection of the patent they take their drawings and specifications to a machine shop or model maker and then the trouble begins. In the first place, the patent drawings are made up regardless of the rules of machine design and due proportions, they are simply intended to show clearly the detail features of the invention. So working drawings must be gotten up in due form, following the patent drawings as closely as is feasible. The machine is then built to fit the patent, as it were. By this time the constructors and the inventors see various details susceptible of improvement, and others are changed to make the form of the machine more suited to be manufactured in quantities by modern machine shop methods.

By this time the action of the machine may have been so changed and improved that a new patent is needed for its present form.

How much better it would have been for him to have at first gone to some trustworthy firm of experience in developing inventions, and, by the aid of their advice and judgment, developed his device on economic lines for factory production. A patent can then be applied for which will be worth much more than one for a hurriedly conceived machine.

A less common but more grievous mistake is for

an inventor to have so little confidence in model makers and so high an opinion of his machine that he grows cunning and attempts to baffle any attempt at stealing his precious idea by having parts of the device constructed in different shops in different towns and then trying to assemble them himself in a locked-up, lonely room. He will probably find enough misfits to give him fits, but as it is usually the quondam inventor of a would-be "perpetual" motion or "power preserver" who is guilty of such methods his punishment is the more suited to the crime.

BOOKS AND SCRAPS.

Assuming that you are collecting a reference library, a brief description of how to open a book is appropriate.

"Hold the book with its back on a smooth or covered table; let the front board down, then the other, holding the leaves in one hand while you open a few leaves at the back, then a few at the front, and so on, alternately opening back and front, gently pressing open the sections till you reach the center of the volume. Do this two or three times and you will obtain the best results. Open the volume violently or carelessly in any one place and you will likely break the back and cause a start in the leaves. Never force the back of the book."*

* From "Modern Bookbinding."

A convenient device recently placed on the market is a loose leaf scrap book. By means of this one may keep all scraps on any one subject together. Like the card index it allows of innumerable classifications. The same thing may be made by getting a stationer to furnish a quantity of manila sheets cut to fit any good self-binder. These sheets when occupied by the scraps are arranged by classes in the binder and are added to whenever extended room on any subject is required.

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